REPORT

OF THE

THIRTY-FIRST MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT MANCHESTER IN SEPTEMBER 1861.

LONDON:
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OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

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

RULES.

ADMISSION OF MEMBERS AND ASSOCIATES.

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

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

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

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

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

COMPOSITIONS, SUBSCRIPTIONS, AND PRIVILEGES.

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

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

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.

I. 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. MAKDOUGALL 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.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
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.
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 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. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S. Professor G. G. Stokes, M.A., D.C.L., Sec. R.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.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE GENERAL TREASURER'S ACCOUNT from 27th June 1860 (commencement of OXFORD MEETING) to 4th September 1861 (at MANCHESTER).

RECEIPTS.

	£ s. d.	£ s. d.
To Balance brought forward from last Account		718 17 8
Life Compositions at Aberdeen and since		250 0 0
Annual Subscriptions, ditto ditto		399 0 0
Associates' Tickets, ditto ditto		636 0 0
Ladies' Tickets, ditto ditto		463 0 0
6 Months' Dividend on £6500 3 per cent. Stock and 12 months on £7000 do.		295 2 6
Sale of Publications—viz.		
For Reports of Meetings	50 14 0	
Catalogue of Stars, Lalande, Dove's Lines, and Lithograph Signature	25 4 2	
		75 18 2
		£2837 18 4

Examined and found correct.

NORTON SHAW,
J. P. GASSIOT,
EDWIN LANKESTER } *Auditors.*

PAYMENTS.

	£ s. d.	£ s. d.
By Expenses of Oxford Meeting, Sundry Printing, Binding Reports, Advertising, and Incidental Payments by the General Treasurer and the Local Treasurers		369 18 1
Printing Report of the Twenty-ninth Meeting	£228 11 8	
Engraving, &c. of the Thirtieth Meeting	65 19 6	
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Report of the Council of the British Association, presented to the General Committee at Manchester, September 4, 1861.

(1) The Council were directed by the General Committee at Oxford to maintain the Establishment of the Kew Observatory by aid of a grant of £500. At each of the meetings of the Council, the Committee of the Observatory have presented a detailed statement of their proceedings, and they have transmitted the General Report for the year 1860–1861, which is annexed.

(2) A sum not exceeding £90 was granted for one year, and placed at the disposal of the Council for the payment of an additional Photographer for carrying on the Photoheliographical Observations at Kew. On this subject the Report of the Kew Committee, which is annexed, may be consulted.

(3) A further sum of £30 was placed at the disposal of Mr. Broun, Dr. Lloyd, and Mr. Stoney, for the construction of an Induction Dip-Circle, in connexion with the Observatory at Kew. The result of this recommendation is stated in the Report of the Kew Committee.

(4) The Report of the Parliamentary Committee has been received by the Council for presentation to the General Committee to-day, and is printed for the information of the Members.

(5) Professor Phillips was requested to complete and print, before the Manchester Meeting, a Classified Index to the Transactions of the Association from 1831 to 1860 inclusive, and was authorized to employ, during this period, an Assistant; and the sum of £100 was placed at his disposal for the purpose.

Professor Phillips reports that he has secured the assistance of Mr. G. Griffith, of Jesus College, Oxford, in carrying on the Index, which had been already much advanced by the help of Mr. Askham, and states that with the aid thus afforded he had hoped to be able to complete the work within the time specified. Though this expectation has not been realized, specimens of the work are laid before the Meeting.

(6) Professor Phillips requested the attention of the Council to circumstances regarding his own health and occupations, which are gradually rendering it necessary for him to prepare to withdraw from the duties of the Assistant General Secretary, which have been for many years intrusted to him; and suggested that opportunity might be taken of this announcement to consider whether the arrangements connected with the Secretariate should remain unchanged, or be modified.

The Council regret to have received letters from Professor Walker, General Secretary, dated 15th March and 20th April, stating that, on account of indisposition which required cessation from labour, it would not be in his power to continue his attention to the official business of the Association at the next Meeting.

Under these circumstances the Council requested Professor Phillips to draw up in writing such statements and suggestions as might appear to him likely to assist the Council in considering the steps to be taken in consequence of these announcements*.

(7) The communication of Professor Phillips in reference to the appointment of a General Secretary having been considered, the following Resolution was adopted:—

That the President, and the gentlemen who have formerly acted as General Secretaries, viz. the Rev. W. V. Harcourt, Sir R. I. Murchison, and

* The statement drawn up by Professor Phillips in consequence of this request was printed in the Minutes of the Council, and separate copies were laid before the General Committee.

Major-General Sabine, together with Professor Phillips, be a Committee to consider and report the steps which they deem it advisable for the Council to take in regard to the appointment of a General Secretary; and that their Report be printed and circulated among the Members of Council previous to their meeting in Manchester on the 4th of September next.

By the following Report, which has been received from these gentlemen, the General Committee will learn with satisfaction that, if it be their pleasure to elect him, the services of a most efficient and experienced Member, who has discharged many offices, including the Presidency, with great benefit to the Association, are at their disposal for the duty of General Secretary.

Report of the Rev. W. V. Harcourt, Sir R. I. Murchison, and Major-General Sabine.

Considering the present state of health of the General Secretary of the British Association, the Rev. Professor Walker, F.R.S., and the announced withdrawal at no distant period of Professor John Phillips, F.R.S., from the post of Assistant General Secretary, which he has so long held, and with such very great advantage to the British Association, we the undersigned, as requested by the Council to propose some suitable arrangement, have now to express our unanimous opinion that Mr. William Hopkins, F.R.S., of St. Peter's College, Cambridge, is eminently qualified to fill the post of Joint General Secretary.

We beg to add that, having applied to Mr. Hopkins, we find that he cordially accepts the offer, and, with the sanction of the Council, will be ready to commence his duties at the ensuing Manchester Meeting.

The consideration of the future relation of Professor Phillips to the British Association is postponed, in compliance with his own request.

William Vernon Harcourt,
Rod. I. Murchison,
Edward Sabine,
Former General Secretaries.

July 25, 1861.

The Council have resolved, in conformity with the recommendation of this Report, to propose to-day in the General Committee that W. Hopkins, Esq., M.A., F.R.S., be elected General Secretary.

(8) The following Foreign gentlemen, eminent in Science, who were present at the late Oxford Meeting and took part in the proceedings, were elected Corresponding Members of the British Association :—

Dr. Bergsma, Utrecht.
Dr. Carus, Leipzig.
Prof. A. Favre, Geneva.
Dr. Geinitz, Dresden.
Dr. Hochstetter, Vienna.
M. Khanikoff, St. Petersburg.
M. Werner Siemens, Vienna.
Prof. B. Pierce, Cambridge, U.S.
Prof. E. Verdet, Paris.

(9) Major-General Sabine communicated a copy of the Statutes of the Humboldt Foundation, now definitely organized, and of a Circular issued by the Committee, announcing that about £8000 had been secured as a Capital Fund, and that about £260 will be available in the year 1862 for the general object of assisting Researches in Natural Science and Travels, in which Humboldt was conspicuously active. The disposition of the fund rests with the Royal Academy of Sciences of Berlin, and is open to applications from Scientific Travellers *of all nations.*

(10) The Council are informed that Invitations will be presented to the General Committee at its Meeting on Monday, September 9, to hold the next meeting in Cambridge. The invitations formerly offered on the part of Birmingham and Newcastle-on-Tyne will be renewed on this occasion; and other invitations will be presented from Bath and Nottingham.

Report of the Kew Committee of the British Association for the Advancement of Science for 1860-1861.

The Committee of the Kew Observatory beg to submit to the Association the following Report of their proceedings during the past year.

It was noticed in a previous Report that General Sabine had undertaken to tabulate the hourly values of the magnetic elements from the curves given by these instruments. These values have been reduced under his superintendence, and some of the results have been embodied in the following papers which he has communicated to the Royal Society:—

(1) On the Solar-diurnal Variation of the Magnetic Declination at Pekin. —Proceedings of the Royal Society, vol. x. p. 360.

(2) On the Laws of the Phenomena of the larger Disturbances of the Magnetic Declination in the Kew Observatory: with notices of the progress of our knowledge regarding the Magnetic Storms.—Proceedings of the Royal Society, vol. x. p. 624.

(3) On the Lunar-diurnal Variation of the Magnetic Declination obtained from the Kew Photograms in the years 1858, 1859, and 1860.—Proceedings of the Royal Society, vol. xi. p. 73.

The Superintendent, Mr. Stewart, has also communicated to the Royal Society a description of the great magnetic storm at the end of August and beginning of September 1859, deduced from the Kew Photographs.

Mr. Chambers continues to be zealously employed in the magnetical department, and attends to the self-recording magnetographs, which have been maintained in constant operation.

The usual monthly absolute determinations of the magnetic elements continue to be made; and the dip observations from November 1857 to the present date (282 in all), a large portion of which were made by the late Mr. Welsh and Mr. Chambers, have been made available by General Sabine in connexion with some previous observations of his own for determining the secular change in the magnetic dip in London, between the years 1821 and 1860. See Proceedings of the Royal Society, vol. xi. p. 144.

The instruments for the Dutch Government alluded to in the last Report have been verified at Kew and taken away. They consisted of a set of self-recording magnetographs with a tabulating instrument, two Dip Circles, and one Fox's Dip Circle for Dr. Bergsma; also of two Unifilars, one for Dr. Bergsma and one for Dr. Buys Ballot.

Shortly after the despatch of these instruments, another set of self-recording Magnetographs were received at Kew, in order to be tested previous to their being sent to Dr. Bache, of the United States, and these were despatched in the early part of this year to America, along with a tabulating instrument, a Unifilar, and Dip Circle, all of which were verified at Kew.

The staff at Kew are at present occupied with a third set of these instruments, along with a Dip Circle and Unifilar, for the University of Coimbra; and Prof. Da Souza of that University is engaged at present at the Kew Observatory in examining his instruments, and in receiving instructions regarding them.

It will thus be seen that no fewer than three sets of these instruments have been furnished during this last year, under the superintendence of the Committee, and it has hitherto been deemed advisable for the interests of science that no charge should be made for their verification. As this, however, is an operation involving labour and a large expenditure of time, an application was made to the Royal Society for the sum of £90 from the Donation Fund, in order to cover the expense of verifying these three sets of instruments, while it was arranged that in future a charge of £30 for verification should be added to the cost of each set. This sum was at once granted by the Council of the Royal Society, and it will be found among the receipts in the financial statement appended to this Report.

In addition to the instruments already mentioned, the following have also been verified at Kew Observatory:—

For the Havana Observatory, a set of differential magnetic instruments, also a Unifilar, Dip Circle, and an altitude and azimuth instrument for absolute determinations of the magnetic elements.

For Dr. Smallwood, Montreal, a Unifilar, Dip Circle, and Differential Declinometer.

For the Astronomer Royal, Greenwich, a 9-inch Unifilar.

For the Rev. W. Scott, Sydney, a Unifilar and Dip Circle.

For Dr. Livingstone, Africa, a Unifilar, Dip Circle, and Azimuth Compass.

For Mr. Jackson, Bach. of Science, Ceylon, a Unifilar and Dip Circle.

Mr. Jackson and M. Capello, of the Lisbon Observatory, have also received instruction at Kew in the use of instruments.

The meteorological work of the Observatory continues to be performed in a satisfactory manner by Mr. George Whipple; and here the Committee desire to mention that, both from the report of the Superintendent and from their own observation, each member of the staff at present attached to the establishment seems to interest himself in the duties he is called upon to discharge.

During the past year, 150 Barometers, 660 Thermometers, and 8 Hydrometers have been verified at the Observatory.

Seven Standard Thermometers have also been constructed and disposed of. Dr. Bergsma and Dr. Buys Ballot were each presented with one of these instruments.

For some time telegraphic reports of the meteorological elements were daily sent to Admiral FitzRoy's office, the expense being defrayed by the Board of Trade; but these despatches were ultimately discontinued, on account of the Board of Trade having only a limited sum disposable for meteorological telegraphy, and Kew being too near London to prove a useful station.

At the last Meeting at Oxford it was announced that the Kew Heliograph was about to be transported to Spain for the purpose of photographing, if possible, the so-called red flames visible on the occasion of a total solar eclipse. That the mission had most successfully accomplished the object contemplated was known in England on the morning of the 19th of July, 1860 (the day after the eclipse), by the publication in the 'Times' newspaper of a telegram sent by Mr. Warren De la Rue from Rivabellosa, near Miranda, where the Kew party were stationed.

It will be remembered that, at the suggestion of the Astronomer Royal, the Admiralty had placed at the disposal of the expedition of astronomers H.M. Ship 'Himalaya,' and that the Government Grant Committee of the Royal Society had voted the sum of £150 for the purpose of defraying the expenses of transporting the Kew Heliograph with a staff of assistants to Spain.

As the scheme became matured, it was deemed desirable to extend considerably the preparations originally contemplated; and actual experience subsequently proved that no provision which had been made could have been safely omitted. Originally it was thought that a mere temporary tent for developing the photographs might have answered the purpose; but on maturing the scheme of operations, it became evident that a complete photographic observatory, with its dark developing-room, cistern of water, sink, and shelves to hold the photographs, would be absolutely necessary to ensure success. An observatory was therefore constructed in such a manner that it could be taken to pieces and made into packages of small weight for easy transport, and at the same time be readily put together again on the locality selected. The house when completed weighed 1248 lbs., and was made up in eight cases. Altogether the packages, including house and apparatus, amounted in number to thirty, and in weight to 34 cwt.

Besides the Heliograph, the apparatus comprised a small transit theodolite for determining the position of the meridian, and ascertaining local time and the latitude and longitude of the station, and also a very fine three-inch achromatic telescope, by Dallmeyer, for the optical observation of the phenomena of the eclipse. Complete sets of chemicals were packed in duplicate in separate boxes, to guard against failure through a possible accident to one set of the chemicals. Collodion of different qualities was made sensitive in London, and some was taken not rendered sensitive, so as to secure as far as possible good results. Distilled water, weighing 139 lbs., had to be included; and engineers' and carpenters' tools, weighing 113 lbs., were taken.

Mr. Casella lent some thermometers and a barometer, and Messrs. Elliott an aneroid barometer to the expedition.

The preparations were commenced by Mr. Beckley (of the Kew Observatory) early in the year 1860; and in June Mr. De la Rue engaged Mr. Reynolds to assist Mr. Beckley in completing them.

Mr. Beckley and Mr. Reynolds were charged with the erection of the Observatory at Rivabellosa; and so well were the plans organized that the Observatory and Heliograph were in actual operation on the 12th of July, the expedition having sailed from Plymouth in the 'Himalaya' on the morning of the 7th. This could not, however, have been so expeditiously accomplished without the energetic cooperation of Mr. Vignoles, who met the 'Himalaya' in a small steamer he had chartered to convey the expedition and their apparatus into the port of Bilbao, and who despatched the Kew apparatus, as soon as it was landed, to the locality he and Mr. De la Rue had agreed upon. This was situated seventy miles distant from the port of landing, and accessible only through a difficult pass. Mr. Vignoles had also taken the trouble to make arrangements for accommodating the Kew party, and for the due supply of provisions—a matter of some importance in such a locality.

Besides Mr. De la Rue, Mr. Beckley, and Mr. Reynolds, the party consisted of Mr. Downes and Mr. E. Beck, two gentlemen who gave their gratuitous services, and of Mr. Clark, who acted as interpreter, also kindly assisting during the eclipse. Each of the party had only one thing to attend to; and thus rapidity of operation and certainty of result were secured.

The total expenditure of this expedition amounted to £512; the balance of £362 over the amount granted by the Royal Society has been generously defrayed by Mr. De la Rue.

Upwards of forty photographs were taken during the eclipse and a little before and after it, two being taken during the totality, on which are depicted the luminous prominences with a precision impossible of attainment by hand drawings. The measurements which have been made of these prominences by Mr. De la Rue show incontrovertibly that they must belong to the sun, and that they are not produced by the deflection of the sun's light through the valleys of the moon. The same prominences, except those covered over during the moon's progress, correspond exactly when one negative is laid over the other; and by copying these by means of a camera, when so placed, a representation is obtained of the whole of the prominences visible during the eclipse in their true relative position. The photographs of the several phases of the eclipse have served to trace out the path of the moon's centre in reference to the sun's centre during the progress of the phenomenon. Now, Rivabellosa being north of the central line of the moon's shadow, the moon's centre did not pass exactly across the sun's centre, but was depressed a little below it, so that a little more of the prominences situated on the north (the upper) limb of the sun became visible than would have been the case exactly under the central line, while, on the other hand, a little of those on the southern limb was shut off. It has been proved, by measuring the photographs, that the moon during the totality covered and uncovered the prominences to the extent of about 94″ of arc in the direction of her path, and that a prominence situated at a right angle to the path shifted its angular position with respect to the moon's centre by lagging behind 5° 55′. On both the photographs is recorded a prominence, not visible optically, showing that photography can render visible phenomena which without its aid would escape observation. Copies of the two totality pictures are being made to illustrate Mr. De la Rue's paper in the Report of the 'Himalaya' Expedition by the Astronomer Royal.

Positive enlarged copies of the phases of the eclipse, nine inches in diameter, have also been made by means of the camera, and will be exhibited at the Manchester Meeting.

The Heliograph has since been replaced in the Observatory; but few opportunities have occurred for using it, in consequence of the pressure of other work; latterly, however, Mr. Beckley has been requested to carry on some experiments with the view of ascertaining whether any more details are rendered visible when the full aperture of 3 inches of the telescope is used, than when it is reduced to about one inch and a half. Up to the present time no definite conclusion can be drawn from the results obtained; so that, at all events, an increase of aperture does not appear to give a strikingly better result when a picture of the same size is taken with various apertures of the object-glass. More experiments, however, are needed before this point, which is one of some importance in guiding us in the construction of future instruments, can be answered definitely. Mr. Beckley has obtained sun-pictures of great beauty during the course of these experiments.

The work of the Kew Observatory is now so increased that it has become absolutely imperative to make some provision for working the Heliograph in a way that will not interfere with the current work of that establishment; and Mr. De la Rue has been requested by his colleagues of the Kew Committee to take charge of the instrument at his observatory, where celestial photography is continuously carried on. This request Mr. De la Rue has kindly acceded to; and he will for a time undertake to record the sun-spots at Cranford, as long as it is found not to interfere with his other observations. Mr. De la Rue has contrived, and had made by Messrs. Simms at his own expense, an instrument for measuring the photographs, which will much facilitate the reduction of the results. It consists of a fixed frame in which work two slides, moving at right angles to each other. Each is furnished with a vernier reading to $\frac{1}{1000}$th of an inch. The top slide works on the lower slide, and carries a hollow axis $4\frac{1}{2}$ inches diameter, on which rotates horizontally a divided circle reading to $10''$, and this carries a second circle on the face of which are fixed four centering screws. An image intended to be measured is placed on the upper circle, and is centred by means of the adjusting screws; it is then adjusted by means of the upper circle in any required angular position with respect to the lower divided circle, so as to bring the cross lines of the photograph in position under a fixed microscope, supported on an arm from the fixed frame. By means of this instrument the sun-pictures are measured so as to determine the diameter to $\frac{1}{2000}$th of the radius; the angular position of any part of a sun-spot and its distance from the centre are thus readily ascertained; or the differences of the right ascension and declination with respect to the centre are as easily read off to the same degree of accuracy.

Mr. De la Rue has recently produced by his large Telescope an image of a solar spot, and portion of the sun's disc, far superior to anything before effected, and which leads to the hope that a new era is opened in heliography, and that the resources of this Observatory might be further developed in that direction.

At the last Meeting of the Association the sum of £90 was voted for an additional photographer, and of this sum £50 has been received. The Committee suggest that the balance of £40 be granted again at this Meeting, as the full sum will be required during the ensuing year. A detailed account of this expenditure will be presented in the next Annual Report.

Allusion was made in last Report to an instrument constructed by Prof. William Thomson, of Glasgow, for determining photographically the electric state of the atmosphere. This instrument has been fitted up at Kew, where it has been in constant operation since the beginning of February last. It has been found to answer well in a photographic point of view, and Prof. Thomson has expressed himself much pleased with the results obtained. The mechanical arrangements connected with the fitting up of this instrument were devised and executed with much skill by Mr. Beckley, the Mechanical Assistant, who has also recently made a working drawing of the instrument for Prof. Thomson, who intends to publish a description of it.

The arrangements made by Mr. Francis Galton, in the Observatory Park, for testing sextants, and which were alluded to in last Report, are now almost complete; and six sextants sent by Captain Washington, R.N., Her Majesty's Hydrographer, have been verified.

The Observatory was honoured with a visit from His Imperial Highness Prince Napoleon on the 9th of September last. His Highness expressed much satisfaction at witnessing the efficient state of the Institution.

Application has been made to the Commissioners for the International Exhibition of 1862, for a space of 40 feet by 20, in which to exhibit as many as possible of the instruments in use at the Observatory, including those which are self-recording.

The Committee desire to express their thanks for a valuable addition which has been made to the Library at Kew, consisting of a very large number of the Greenwich publications, presented to them through the kindness of the Astronomer Royal.

It will be observed by the annexed statement that the expenditure of last year has exceeded the income by about £90; but as this year comprised five quarters, it is hoped that the usual annual grant of £500 will cover the expense until the next Meeting of the Association.

Kew Observatory,
August 30, 1861.

JOHN P. GASSIOT,
Chairman.

Accounts of the Kew Committee of the British Association from June 18, 1860, *to September* 4, 1861.

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance from last account				11	8	5
Received from the General Treasurer				500	0	0
„ for the verification of Instruments—						
from the Board of Trade	7	18	0			
from the Admiralty	17	6	0			
from Opticians	56	1	0			
				81	5	0
„ from the Donation Fund of the Royal Society for the verification of Magnetographs				90	0	0
„ from Prof. Wm. Thomson for expenses connected with his self-recording Electrometer and labour bestowed upon it				36	15	8
Balance				79	3	7
				£798	12	8

PAYMENTS.

	£	s.	d.	£	s.	d.
Salaries, &c. :—						
To B. Stewart, five quarters, ending October 1, 1861	250	0	0			
Ditto, allowed for petty travelling expenses	10	0	0			
C. Chambers, five quarters, ending October 6, 1861	125	0	0			
G. Whipple, four quarters, ending June 18, 1861	40	0	0			
Ditto, one quarter, ending September 18, 1861	12	10	0			
R. Beckley, 62 weeks, ending September 2, 1861, at 40*s.*	124	0	0			
T. Baker, 11 weeks, ending September 10, 1860, at 8*s.*	4	8	0			
Ditto, 26 weeks, ending March 11, 1861, at 10*s.*	13	0	0			
Ditto, 25 weeks, ending September 2, 1861, at 12*s.*	15	0	0			
				593	18	0
Apparatus, Materials, Tools, &c.				43	14	1
Ironmonger, Carpenter, and Mason				30	6	9
Printing, Stationery, Books, and Postage				23	10	9
Coals and Gas				49	0	2
House Expenses, Chandlery, &c.				17	16	2
Porterage and petty expenses				12	6	9
Cost of surrounding enclosure with a ditch, and of planting a hedge				17	10	0
Rent of Land to 10th October, 1861				10	10	0
				£798	12	8
Balance				79	3	7

I have examined the above account and compared it with the vouchers presented to me, and I find that the amounts expended exceed those received by the sum of £79 3*s.* 7*d.*; and that the expenditure for salaries, &c. this year is for one year and a quarter, that in the last account having been for three-quarters of a year only.

16*th August*, 1861. R. HUTTON.

Report of the Parliamentary Committee to the Meeting of the British Association at Manchester, in September 1861.

The Parliamentary Committee have the honour to report:—

That on the 19th of July they met the Steam Performance Committee, by appointment, at the Admiralty, and had, in company with the Members of that Committee, an interview with the Duke of Somerset.

That in the course of that interview the Chairman of your Committee shortly explained the motives which had induced the British Association to appoint the Steam Performance Committee, and called upon Mr. Fairbairn, who thereupon stated and explained the principal suggestions contained in the Report of the Steam Performance Committee, which had been prepared and agreed upon, and will be presented to this Meeting; and urged upon His Grace the expediency of carrying them into effect.

The Duke of Somerset, in reply, stated certain objections which he entertained to some of the suggestions, founded chiefly upon the circumstances that sufficient time could not be allowed for the various experiments consistently with the interests of the service, and that the ships of the Royal Navy only employed steam occasionally, and only as an auxiliary power; but His Grace was understood to agree to supply such information to the scientific public as could be done without improperly interfering with the performance of ordinary duties.

The Dukes of Devonshire and Argyll, the Earls of Enniskillen, Harrowby, Rosse and De Grey, Lord Stanley and Sir John Pakington, must be considered as having vacated their seats in your Committee, in pursuance of the resolution adopted at Liverpool in 1854; but your Committee recommend that they should be re-elected. Your Committee also recommend that the two vacancies in the House of Commons List be filled by the election of Sir Joseph Paxton and Lieut.-Col. Sykes.

WROTTESLEY, *Chairman.*

RECOMMENDATIONS ADOPTED BY THE GENERAL COMMITTEE AT THE MANCHESTER MEETING IN SEPTEMBER 1861.

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

Involving Grants of Money.

That the sum of £500 be appropriated, under the sanction of the Council, for maintaining the Establishment at Kew.

That the sum of £40 be placed at the disposal of the Kew Committee for the employment of the Photo-heliometer.

That the cooperation of the Royal Society be requested in obtaining a series of photographic pictures of the Solar Surface; and that the sum of £150 be placed at the disposal of the Kew Committee for the purpose.

That Professor Airy, Lord Wrottesley, Sir D. Brewster, Col. Sykes, Sir J. Herschel, General Sabine, Dr. Lloyd, Admiral FitzRoy, Dr. Lee, Dr. Robinson, Mr. Gassiot, Mr. Glaisher, Dr. Tyndall, and Dr. W. A. Miller be requested to form a Balloon Committee; and that the sum of £200 be placed at their disposal for the purpose.

That Professor Williamson, Professor Wheatstone, Professor W. Thomson, Professor Miller (of Cambridge), Dr. Matthiessen, and Mr. F. Jenkin be a

Committee to report upon Standards of Electrical Resistance; and that the sum of £50 be placed at their disposal for the purpose.

That Mr. J. Glaisher, Mr. R. P. Greg, Mr. E. W. Brayley, and Mr. Alex. Herschel be a Committee to report upon Luminous Meteors and Aërolites; and that the sum of £20 be placed at their disposal for the purpose.

That Mr. Fleeming Jenkin be requested to continue his Experiments for determining the Laws of Permanent Thermo-electric Currents in broken metallic circuits, and to report thereon; and that the sum of £20 be placed at his disposal for the purpose.

That Professor Hennessy, Admiral FitzRoy, and Mr. Glaisher be a Committee to study, by the aid of instruments specially devised for the purpose, the connexion of small vertical disturbances of the atmosphere with storms, and to report thereon; and that the sum of £20 be placed at their disposal for the purpose.

That Mr. Alphonse Gages be requested to continue his Researches on Mechanico-Chemical Analysis of Minerals; and that the sum of £8 remaining undrawn from the grant of last year be again placed at his disposal for the purpose.

That Dr. Hooker, Mr. Binney, and Professor Morris be a Committee to prepare a Report on the connexion between the external form and internal microscopical structure of the Fossil Wood from the Lower Coal-Measures of Lancashire; and that the sum of £40 be placed at their disposal for the purpose.

That Sir C. F. Bunbury*, Mr. Binney, and Mr. H. Ormerod be requested to prepare a Report on the Flora of the Lancashire Coal-fields; and that the sum of £40 be placed at their disposal for the purpose.

That Mr. R. H. Scott, Sir Richard Griffith, Bart., and the Rev. Professor Haughton be a Committee to prepare a Report on the Chemical and Mineralogical Composition of the Granites of Donegal and the Rocks associated therewith; and that the sum of £25 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Mr. Alder, and the Rev. Thomas Hincks be a Committee to Dredge the Dogger Bank and portions of the Sea Coast of Durham and Northumberland; and that the sum of £25 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Dr. Dickie, Professor Nicol, Dr. Dyce, and Dr. Ogilvie be a Committee for Dredging on the North and East Coasts of Scotland; and that the sum of £25 be placed at their disposal for the purpose.

That Mr. Gwyn Jeffreys, Dr. Kinahan, Dr. Carter, and Mr. E. Waller be a Committee for conducting the Dredging Report of the Bay of Dublin; and that the sum of £15 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Dr. Collingwood, Mr. Isaac Byerley, Rev. H. H. Higgins, and Dr. Edwards be a Committee to Dredge the River Mersey and Dee; and that the sum of £5 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Dr. Lukis, Mr. C. Spence Bate, Mr. A. Hancock, Dr. Verloren, and Professor Archer be a Committee for the purpose of Reporting on the best mode of preventing the ravages of the different kinds of Teredo and other Animals in our Ships and Harbours; and that the sum of £10 be placed at their disposal for the purpose.

That Dr. P. Lutley Sclater, Mr. R. J. Tomes, and Dr. Günther be a Committee to Report on the Present State of our Knowledge of the West Indian Vertebrata; and that the sum of £10 be placed at their disposal for the purpose.

* Sir C. F. Bunbury has declined to act.

That Dr. P. Lutley Sclater and Dr. F. Hochstetter be a Committee for the purpose of continuing their investigations as to the Species of *Apteryx* in New Zealand; and that the sum of £50 be placed at their disposal for the purpose.

That Dr. E. Perceval Wright and Professor W. H. Harvey be a Committee to draw up a Report on the Fishes of Dublin Bay and the Coasts of Leinster; and that the sum of £10 be placed at their disposal for the purpose.

That Dr. P. Lutley Sclater and Dr. E. Perceval Wright be a Committee to assist Dr. P. P. Carpenter in preparing a Supplementary Report on the Mollusca of N.W. America; and that the sum of £10 be placed at their disposal for the purpose.

That Dr. Collingwood, Mr. John Lubbock, Mr. R. Patterson, Dr. P. P Carpenter, Mr. J. A. Turner, M.P., and the Rev. H. H. Higgins be a Committee to Report on the Collecting of Objects of Natural History by the Mercantile Marine, with £5 at their disposal for the purpose.

That Dr. Edward Smith, F.R.S., and Mr. W. R. Milner be requested to continue their inquiries into the influence of Prison Discipline and Dietary over the Bodily Functions of Prisoners; and that the sum of £20 be placed at their disposal for the purpose.

That Mr. Thomas Webster, the Right Hon. Joseph Napier, Sir W. Armstrong, Mr. W. Fairba rn, Mr. W. R. Grove, Mr. James Heywood, and General Sabine be a Committee (with power to add to their number) for the purpose of taking such steps as may appear expedient for rendering the Patent Law more efficient for the reward of the meritorious Inventor and the advancement of Practical Science; and that the sum of £50 be placed at their disposal for the purpose.

That Professor J. Thomson be requested to complete his Report of Experiments on the Gauging of Water; and that the sum of £15 be placed at his disposal for the purpose.

That Mr. William Fairbairn, Mr. J. E. M^cConnell, and Mr. William Smith be a Committee (with power to add to their number) to investigate and report on some of the Causes of Accidents on Railways, more particularly those accidents consequent upon the failure of the materials and apparatus used in the Construction and Working of Railways, and in the Rolling Stock; that the sum of £25 be placed at their disposal for the purpose.

That the Committee on Steam-ship Performance be reappointed; that the attention of the Committee be also directed to the obtaining of information respecting the performance of vessels under Sail, with a view to comparing the results of the two powers of Wind and Steam, in order to their more effective and economical combination; and that the sum of £150 be placed at their disposal. That the following noblemen and gentlemen be requested to serve on the Committee, with power to add to their number:—The Duke of Sutherland; The Earl of Gifford, M.P.; The Earl of Caithness; Lord Dufferin; Mr. William Fairbairn, F.R.S.; Mr. J. Scott Russell, F.R.S.; Admiral Paris; The Hon. Captain Egerton, R.N.; The Hon. Leopold Agar Ellis, M.P.; Mr. J. E. M^cConnell; Mr. W. Smith; Professor J. Macquorn Rankine; Mr. James R. Napier; Mr. Richard Roberts; Mr. Henry Wright, to be Honorary Secretary.

That Mr. J. Oldham, C.E., Mr. J. F. Bateman, Mr. J. Scott Russell, and Mr. T. Thompson be a Committee to conduct a series of Tidal Observations in the Humber; and that the sum of £25 be placed at their disposal for the purpose.

That the sum of £600 be appropriated for the purpose of printing an Index to the Volumes of Reports and Sectional Proceedings of the Association, from 1831 to 1860 inclusive.

That Professor Phillips be authorized to employ for the ensuing year an Assistant, and that the sum of £100 be placed at his disposal for the purpose.

Applications for Reports and Researches not involving Grants of Money.

That Professor G. G. Stokes be again requested to furnish a Report on Physical Optics.

That Mr. A. Cayley be again requested to furnish a Report on the Recent Progress in the Solution of certain Problems in Dynamics.

That Mr. Archibald Smith and Mr. F. J. Evans be requested to abstract and report upon the three Reports of the Liverpool Compass Committee, and other recent publications on the same subject.

That Mr. Johnstone Stoney be requested to report on the Present State of Molecular Physics.

That Dr. Lloyd, General Sabine, Mr. A. Smith, Mr. G. Johnstone Stoney, Professor Airy, Professor Donkin, Professor W. Thomson, Mr. Cayley, and the Rev. Professor Price be requested to inquire into the adequacy of existing data for carrying into effect the suggestion of Gauss to apply his General Theory of Magnetism to Magnetic Variations; and to report on the steps proper to be taken to supply what may still be wanting, and generally on the course to be adopted to carry out Gauss's suggestion.

That Dr. Crace Calvert be requested to draw up a Report on the Chemical Composition and Physical Properties of the Wood employed for Naval Construction.

That Dr. Williamson, Dr. W. A. Miller, Dr. Andrews, Professor Brodie, Professor W. H. Miller, Dr. Lyon Playfair, and Dr. Angus Smith (with power to add to their number) be requested to inquire into the best means of effecting a registration and publication of the Numerical Facts of Chemistry.

That Dr. Williamson, Dr. Angus Smith, Dr. Christison, Mr. W. De la Rue, Mr. Grove, Mr. Webster, Mr. Bateman, Rev. W. Vernon Harcourt, Professor Brodie, and Professor W. A. Miller be requested to consider whether any improvements can be suggested in the present practice respecting scientific evidence, as taken in courts of law, and to report any such suggestions of improvement as may appear practicable to the ensuing Meeting at Cambridge; that the Committee have power to add to their number.

That Mr. J. Gwyn Jeffreys, Mr. R. MacAndrew, Mr. G. C. Hyndman, Dr. Edwards, Dr. Dickie, Mr. C. L. Stewart, Dr. Collingwood, Dr. Kinahan, Mr. J. S. Worthey, Dr. E. Perceval Wright, Mr. J. Ray Greene, Rev. Thomas Hincks, and Mr. R. D. Darbyshire to act as a General Dredging Committee, with a general superintendence of all other Dredging Committees appointed by the Association.

That M. Foster, M.D. be reappointed to report upon the Present State of our Knowledge in reference to Muscular Irritability, he having been unable from ill health to prepare it for the present Meeting.

That Admiral Sir E. Belcher, Sir J. Rennie, Mr. G. Rennie, and Mr. Smith be requested to report on the Rise and Progress of Steam Navigation in the Port of London.

That Mr. W. Fairbairn, Mr. J. F. Bateman, Professor Thomson, and Mr. J. G. Lynde be requested to report on Experiments to be made at the Manchester Waterworks on the Gauging of Water; with power to add to their number.

That in the opinion of the Committee a large and extensive Reform in the

Patent Laws and their administration is necessary and urgent; that the discussion which took place indicated the means for effecting such reform; that the Parliamentary Committee of this Association might be advantageously employed in bringing the subject before Parliament, and that they be requested to give their attention to the subject, and to take the necessary steps for the purpose. That Mr. Webster and Mr. Grove be requested to make the communication to the Parliamentary Committee.

The following recommendation was referred to the Parliamentary Committee:—"That application be made to the Charity Commissioners of England and Wales to provide sufficient means for the Classification and Condensation of the Accounts of Charities sent in Annually to the Charity Commissioners." That Mr. Heywood be requested to communicate with the Parliamentary Committee.

Involving Applications to Government or Public Institutions.

That a Committee, consisting of Dr. Robinson, Professor Wheatstone, and Dr. Gladstone, be requested to make application to the Board of Trade for Experiments on the Transmission of Sound Signals during Fogs.

That it be represented to the Secretary of State for India, that inquiries into Prisons similar to those made by Dr. Mouat on the Prisons of Bengal, as detailed by him from his printed Reports, be instituted in the other Presidencies of India, especially in those of the Punjaub and the North-West Provinces.

That Dr. Davy, Dr. Smith, and Mr. Miller be a Committee to make a representation in this matter to the Secretary of State for India.

Communications to be printed entire among the Reports.

That Dr. Lloyd's Paper, on the Secular Changes of Terrestrial Magnetism and their Connexion with Disturbances, be printed entire in the Sectional Proceedings of the Association.

That the Report of Drs. Schunck, Smith, and Roscoe, on the Recent Progress and Present Condition of Manufacturing Chemistry in the South Lancashire District, be printed entire among the Reports.

That Dr. James Hunt's Paper, on the Acclimatization of Man, be printed entire among the Reports.

That Mr. Charles Atherton's Paper, on Freight as affected by difference of the Dynamic Performance of Steam-Ships, be printed entire among the Reports.

That Mr. E. J. Reed's Paper, on the Iron-Cased Ships of the British Admiralty, be printed entire in the Sectional Proceedings.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Manchester Meeting in September 1861, *with the name of the Member, who alone, or as the First of a Committee, is entitled to draw the Money.*

Kew Observatory.	£	*s.*	*d.*
For maintaining the Establishment at Kew........................	500	0	0
Carried forward......	£500	0	0

	£	s.	d.
Brought forward......	500	0	0
For Photo-heliometry at Kew	40	0	0
For Photographic pictures of the Sun	150	0	0
Mathematics and Physics.			
SYKES, Colonel, and Committee.—Balloon Ascents	200	0	0
WILLIAMSON, Professor, and Committee.—Electrical Resistance	50	0	0
GLAISHER, Mr., and Committee.—Luminous Meteors	20	0	0
JENKIN, Mr.—Thermo-Electricity	20	0	0
HENNESSY, Professor, and Committee.—Connexion of Storms	20	0	0
Chemical Science.			
GAGES, Mr.—Analysis of Rocks	8	0	0
Geology.			
HOOKER, Dr., and Committee.—Lancashire Fossil Wood	40	0	0
HOOKER, Dr., and Committee.—Lancashire Carbonaceous Flora	40	0	0
SCOTT, Mr., and Committee.—Rocks of Donegal	25	0	0
Zoology and Botany.			
JEFFREYS, Mr., and Committee.—Dredging Coasts of Durham and Northumberland	25	0	0
JEFFREYS, Mr., and Committee.—Dredging North-East Coast of Ireland	25	0	0
JEFFREYS, Mr., and Committee.—Dredging in Dublin Bay ...	15	0	0
JEFFREYS, Mr., and Committee.—Dredging in the Mersey ...	5	0	0
JEFFREYS, Mr., and Committee.—Ravages of Teredo	10	0	0
SCLATER, Dr., and Committee.—West Indian Vertebrata	10	0	0
SCLATER, Dr., and Committee.—Apteryx	50	0	0
WRIGHT, Dr., and Committee.—Fishes in Dublin Bay	10	0	0
SCLATER, Dr., and Committee.—Mollusca, N.W. America ...	10	0	0
COLLINGWOOD, Dr., and Committee.—Collecting of Natural History	5	0	0
Physiology.			
SMITH, Dr. E., and Mr. MILNER.—Effects of Prison Discipline	20	0	0
Mechanical Science.			
WEBSTER, Mr., and Committee.—On Patent Laws...............	50	0	0
THOMSON, Professor J.—Gauging	15	0	0
FAIRBAIRN, Mr., and Committee.—Railway Accidents.........	25	0	0
SUTHERLAND, Duke of, and Committee.—Steam-ship Performance	150	0	0
OLDHAM, Mr., and Committee.—Tide Observations, Humber	25	0	0
For Printing of Index to Reports and Transactions and Sections, from 1831 to 1860 inclusive	600	0	0
For Assistance to Professor Phillips..............................	100	0	0
Total	£2263	0	0

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	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument, 1842	10	3	6
	£981	12	8

1845.

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

	£	s.	d.
Periodical Phenomena	15	0	0
Meteorological Instrument, Azores	25	0	0
	£345	18	0

1851.

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

1852.

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

1853.

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

1854.

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

1855.

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

1856.

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

1857.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments..	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland..........................	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar..	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	£507	15	4

1858.

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

1859.

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

1860.	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura 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

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.

In each Committee, the Member first named is the person entitled to call on the Treasurer, William Spottiswoode, Esq., 19 Chester Street, Belgrave Square, 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, September 4, at 8 P.M., in the Free Trade Hall, The Lord Wrottesley, F.R.S., resigned the office of President to William Fairbairn, Esq., F.R.S., who took the Chair and delivered an Address, for which see page li.

On Thursday Evening, September 5, at 8 P.M., a Soirée, with Microscopes, took place in the Free Trade Hall.

On Friday Evening, September 6, at 8 P.M., in the Concert Room, Professor W. A. Miller, F.R.S., delivered a Discourse on Spectrum Analysis.

On Saturday Evening, September 7, at 8 P.M., a Soirée, with Telegraphs, took place in the Free Trade Hall.

On Monday Evening, September 9, at 8 P.M., Professor Airy, Astronomer Royal, delivered a Discourse on the late Eclipse of the Sun.

On Tuesday Evening, September 10, at 8 P.M., the attention of the Members was called by Dr. E. Lankester, F.R.S., to the labours of the Field Naturalist's Society, and to the large collections in Natural History placed in the Free Trade Hall.

On Wednesday, September 11, at 3 P.M., the concluding General Meeting took place in the Free Trade Hall, when the Proceedings of the General Committee, and the Grants of Money for Scientific purposes, were explained to the Members.

The Meeting was then adjourned to Cambridge*.

* The Meeting is appointed to take place on Wednesday, the 1st of October, 1862.

ADDRESS

BY

WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S.

Gentlemen,—Ever since my election to the high office I now occupy, I have been deeply sensible of my own unfitness for a post of so much distinction and responsibility. And when I call to mind the illustrious men who have preceded me in this Chair, and see around me so many persons much better qualified for the office than myself, I feel the novelty of my position and unfeigned embarrassment in addressing you.

I should, however, very imperfectly discharge the duties which devolve upon me, as the successor of the distinguished nobleman who presided over the meetings of last year, if I neglected to thank you for the honourable position in which you have placed me, and to express, at the outset, my gratitude to those valued friends with whom I have been united for many years in the labours of the Sections of this Association, and from whom I have invariably received every mark of esteem.

A careful perusal of the history of this Association will demonstrate that it was the first and for a long time the only institution which brought together for a common object the learned Professors of our Universities and the workers in practical science. These periodical reunions have been of incalculable benefit, in giving to practice that soundness of principle and certainty of progressive improvement, which can only be obtained by the accurate study of science and its application to the arts. On the other hand, the men of actual practice have reciprocated the benefits thus received from theory, in testing by actual experiment deductions which were doubtful, and rectifying those which were erroneous. Guided by an extended experience, and exercising a sound and disciplined judgment, they have often corrected theories apparently accurate, but nevertheless founded on incomplete data or on false assumptions inadvertently introduced. If the British Association had effected nothing more than the removal of the anomalous separation of theory and practice, it would have gained imperishable renown in the benefit thus conferred.

Were I to enlarge on the relation of the achievements of science to the comforts and enjoyments of man, I should have to refer to the present epoch as one of the most important in the history of the world. At no former period did science contribute so much to the uses of life and the wants of society. And in doing this it has only been fulfilling that mission which Bacon, the great father of modern science, appointed for it, when he wrote that "the legitimate goal of the sciences is the endowment of human life with new inventions and riches," and when he sought for a natural philosophy which, not spending its energy on barren disquisitions, "should be operative for the benefit and endowment of mankind."

Looking, then, to the fact that, whilst in our time all the sciences have yielded this fruit, Engineering science, with which I have been most intimately connected, has preeminently advanced the power, the wealth, and the comforts of mankind, I shall probably best discharge the duties of the office I have the honour to fill, by stating as briefly as possible the more recent scientific discoveries which have so influenced the relations of social life. I shall, therefore, not dwell so much on the progress of abstract science, important as that is, but shall rather endeavour briefly to examine the application of science to the useful arts, and the results which have followed, and are likely to follow, in the improvement of the condition of society.

The history of man throughout the gradations and changes which he undergoes in advancing from a primitive barbarism to a state of civilization, shows that he has been chiefly stimulated to the cultivation of science and the development of his inventive powers by the urgent necessity of providing for his wants and securing his safety. There is no nation, however barbarous, which does not inherit the germs of civilization, and there is scarcely any which has not done something towards applying the rudiments of science to the purposes of daily life.

Amongst the South Sea Islanders, when discovered by Cook, the applied sciences (if I may use the term) were not entirely unknown. They had observed something of the motions of the heavenly bodies, and watched with interest their revolutions, in order to apply this knowledge to the division of time. They were not entirely deficient in the construction of instruments of husbandry, of war, and of music. They had made themselves acquainted with the rudiments of shipbuilding and navigation, in the construction and management of their canoes. Cut off from the influence of European civilization, and deprived of intercourse with higher grades of mind, we still find the inherent principle of progression exhibiting itself, and the inventive and reasoning powers developed in the attempt to secure the means of subsistence.

Again, if we compare man as he exists in small communities with his condition where large numbers are congregated together, we find that densely populated countries are the most prolific in inventions, and advance most rapidly in science. Because the wants of the many are greater than those of the few, there is a more vigorous struggle against the natural limitations of supply, a more careful husbanding of resources, and there are more minds at work.

This fact is strikingly exemplified in the history of Mexico and Peru, and its attestation is found in the numerous monuments of the past which are seen in Central America, where the remains of cities and temples, and vast public works, erected by a people endowed with high intellectual acquirements, can still be traced. There have been discovered a system of canals for irrigation; long mining-galleries cut in the solid rock, in search of lead, tin, and copper; pyramids not unlike those of Egypt; earthenware vases and cups, and manuscripts containing the records of their history; all testifying to so high a degree of scientific culture and practical skill that, looking at the cruelties which attended the conquests of Cortes and Pizarro, we may well hesitate as to which had the stronger claims on our sympathy, the victors or the vanquished.

In attempting to notice those branches of science with which I am but imperfectly acquainted, I shall have to claim your indulgence. This Association, as you are aware, does not confine its discussions and investigations to any particular science; and one great advantage of this is, that it leads to the division of labour, whilst the attention which each department receives, and the harmony with which the plan has hitherto worked, afford the best guarantee of its wisdom and proof of its success.

In the early history of Astronomy, how vague and unsatisactory were the wild theories and conjectures which supplied the place of demonstrated physical truths and carefully observed laws! How immeasurably small, what a very speck does man appear, with all the wonders of his invention, when contrasted with the mighty works of the Creator; and how imperfect is our apprehension, even in the highest flights of poetic imagination, of the boundless depths of space! These reflections naturally suggest themselves in the contemplation of the works of an Almighty Power, and impress the mind with a reverential awe for the great Author of our existence.

The great revolution which laid the foundation of modern Astronomy, and which, indeed, marks the birth of modern physical science, is chiefly due to three or four distinguished philosophers. Tycho Brahe, by his system of accurate measurement of the positions of the heavenly bodies, Copernicus, by his theory of the solar system, Galileo, by the application of the telescope, and Kepler, by the discovery of the laws of the planetary motions, all assisted in advancing, by prodigious strides, towards a true knowledge of the constitution of the universe. It remained for Newton to introduce, at a later period, the idea of an attraction varying directly as the mass, and inversely as the square of the distance, and thus to reduce celestial phenomena to the greatest simplicity, by comprehending them under a single law. Without tracing the details of the history of this science, we may notice that in more recent times astronomical discoveries have been closely connected with high mechanical skill in the construction of instruments of precision. The telescope has enormously increased the catalogue of the fixed stars, or those "landmarks of the universe," as Sir John Herschel terms them, "which never deceive the astronomer, navigator, or surveyor." The number of known planets and asteroids has also been greatly enlarged. The discovery of Uranus resulted immediately from the perfection attained by Sir William Herschel in the construction of his telescope. More recently, the structure of the nebulæ has been unfolded through the application to their study of the colossal telescope of Lord Rosse. In all these directions much has been done both by our present distinguished Astronomer Royal and also by amateur observers in private observatories, all of whom, with Mr. Lassell at their head, are making rapid advances in this department of physical science.

Our knowledge of the physical constitution of the central body of our system seems likely, at the present time, to be much increased. The spots on the sun's disk were noticed by Galileo and his contemporaries, and enabled them to ascertain the time of its rotation and the inclination of its axis. They also correctly inferred, from their appearance, the existence of a luminous envelope, in which funnel-shaped depressions revealed a solid and dark nucleus. Just a century ago, Alexander Wilson indicated the presence of a second and less luminous envelope beneath the outer stratum, and his discovery was confirmed by Sir William Herschel, who was led to assume the presence of a double stratum of clouds, the upper intensely luminous, the lower grey, and forming the penumbra of the spots. Observations during eclipses have rendered probable the supposition of a third and outermost stratum of imperfect transparency enclosing concentrically the other envelopes. Still more recently, the remarkable discoveries of Kirchhoff and Bunsen require us to believe that a solid or liquid photosphere is seen through an atmosphere containing iron, sodium, lithium, and other metals in a vaporous condition.

We must still wait for the application of more perfect instruments, and especially for the careful registering of the appearances of the sun by the photoheliograph of Sir John Herschel, so ably employed by Mr. Warren De la Rue, Mr. Welsh, and others, before we can expect a solution of all the problems thus suggested.

Guided by the same principles which have been so successful in Astronomy, its sister science, Magnetism, emerging from its infancy, has of late advanced rapidly in that stage of development which is marked by assiduous and systematic observation of the phenomena, by careful analysis and presentation of the facts which they disclose, and by the grouping of these in generalizations, which, when the basis on which they rest shall be more extended, will prepare the way for the conception of a general physical theory, in which all the phenomena shall be comprehended, whilst each shall receive its separate and satisfactory explanation.

It is unnecessary to remind you of the deep interest which the British Association has at all times taken in the advancement of this branch of natural knowledge, or of the specific recommendations which, made in conjunction with the Royal Society, have been productive of such various and important results. To refer but to a single instance, we have seen those *magnetic disturbances*,—so mysterious in their origin and so extensive in simultaneous prevalence, and which, less than twenty years ago, were designated by a term specially denoting that their laws were wholly unknown,—traced to laws of periodical recurrence, revealing, without a doubt, their origin in the central body of our system, by inequalities which have for their respective periods, the solar day, the solar year, and still more remarkably, an until lately unsuspected solar cycle of about ten of our terrestrial years, to whose existence they bear testimony in conjunction with the solar spots, but whose nature and causes are in all other respects still wrapped in entire obscurity. We owe to General Sabine, especially, the recognition and study of these and other solar magnetic influences and of the magnetic influence of the moon similarly attested by concurrent determinations in many parts of the globe, which are now held to constitute a distinct branch of this science not inappropriately named "celestial," as distinguished from purely terrestrial magnetism.

We ought not in this town to forget that the very rapid advance which has been made in our time by Chemistry is due to the law of equivalents, or atomic theory, first discovered by our townsman, John Dalton. Since the development of this law its progress has been unimpeded, and it has had a most direct bearing on the comforts and enjoyments of life. A knowledge of the constituents of food has led to important deductions as to the relative nutritive value and commercial importance of different materials. Water has been studied in reference to the deleterious impurities with which it is so apt to be contaminated in its distribution to the inhabitants of large towns. The power of analysis, which enables us to detect adulterations, has been invaluable to the public health, and would be much more so, if it were possible to obviate the difficulties which have prevented the operation of recent legislation on this subject.

We have another proof of the utility of this science in its application to medicine; and the estimation in which it is held by the medical profession is the true index of its value in the diagnosis and treatment of disease. The largest developments of chemistry, however, have been in connexion with the useful arts. What would now be the condition of calico-printing, bleaching, dyeing, and even agriculture itself, if they had been deprived of the aid of theoretic chemistry?

For example, Aniline—first discovered in coal-tar by Dr. Hofmann, who has so admirably developed its properties—is now most extensively used as the basis of red, blue, violet, and green dyes. This important discovery will probably in a few years render this country independent of the world for dye-stuffs; and it is more than probable that England, instead of drawing her dye-stuffs from foreign countries, may herself become the centre from which all the world will be supplied.

It is an interesting fact that at the same time in another branch of this science, M. Tournet has lately demonstrated that the colours of gems, such as the emerald, aqua-marina, amethyst, smoked rock-crystal, and others, are due to volatile hydrocarbons, first noticed by Sir David Brewster in clouded topaz, and that they are not derived from metallic oxides, as has been hitherto believed.

Another remarkable advance has recently been made by Bunsen and Kirchhoff in the application of the coloured rays of the prism to analytical research. We may consider their discoveries as the commencement of a new era in analytical chemistry, from the extraordinary facilities they afford in the qualitative detection of the minutest traces of elementary bodies. The value of the method has been proved by the discovery of the new metals Cæsium and Rubidium by M. Bunsen, and it has yielded another remarkable result in demonstrating the existence of iron, and six other known metals, in the sun.

In noticing the more recent discoveries in this important science, I must not pass over in silence the valuable light which chemistry has thrown upon the composition of iron and steel. Although Despretz demonstrated many years ago that iron would combine with nitrogen, yet it was not until 1857 that Mr. C. Binks proved that nitrogen is an essential element of steel, and more recently M. Carou and M. Fremy have further elucidated this subject; the former showing that cyanogen, or cyanide of ammonium, is the essential element which converts wrought iron into steel; the latter combining iron with nitrogen through the medium of ammonia, and then converting it into steel by bringing it at the proper temperature into contact with common coal-gas. There is little doubt that in a few years these discoveries will enable Sheffield manufacturers to replace their present uncertain, cumbrous, and expensive process, by a method at once simple and inexpensive, and so completely under control as to admit of any required degree of conversion being obtained with absolute certainty. Mr. Crace Calvert also has proved that cast iron contains nitrogen, and has shown that it is a definite compound of carbon and iron mixed with various proportions of metallic iron, according to its nature.

Before leaving chemical science, I must refer to the interesting discovery by M. Deville, by which he succeeded in rapidly melting thirty-eight or forty pounds of platinum—a metal till then considered almost infusible. This discovery will render the extraction of platinum from the ore more perfect, and, by reducing its cost, will greatly facilitate its application to the arts.

It is little more than half a century since Geology assumed the distinctive character of a science. Taking into consideration the aspects of nature in different epochs of the history of the earth, it has been found that the study of the changes at present going on in the world around us enable us to understand the past revolutions of the globe, and the conditions and circumstances under which strata have been formed and organic remains imbedded and preserved. The geologist has increasingly tended to believe that the changes which have taken place on the face of the globe, from the earliest times to the present, are the result of agencies still at work. But whilst it is his high office to record the distribution of life in past ages and the evidence of physical changes in the arrangement of land and water, his results hitherto have indicated no traces of its beginning, nor have they afforded evidence of the time of its future duration. Geology has been indebted for this progress very largely to the investigations of Sedgwick and the writings of Sir Charles Lyell.

As an example of the application of geology to the practical uses of life, I may cite the discovery of the gold-fields of Australia, which might long have remained hidden, but for the researches of Sir Roderick Murchison in the Ural Mountains on the geological position of the strata from which the Russian gold is obtained. From this investigation he was led by inductive reasoning to believe that gold would be found in similar rocks, specimens of which had been sent him from Australia. The last years of the active life of this distinguished geologist have been devoted to the re-examination of the rocks of his native Highlands of Scotland. Applying to them those principles of classification which he long since established, he has demonstrated that the crystalline limestone and quartz-rocks which are associated with mica schists, &c., belong by their imbedded organic remains to the Lower Silurian rocks. Descending from this well-marked horizon, he shows the existence beneath all such fossiliferous strata of vast masses of sandstone and conglomerate of Cambrian age; and, lastly, he has proved the existence of a fundamental gneiss, on which all the other rocks repose, and which, occupying the North-western Hebrides and the west coasts of Sutherland and Ross, is the oldest rock-formation on the British Isles, it being unknown in England, Wales, or Ireland.

It is well known that the temperature increases, as we descend through the earth's crust, from a certain point near the surface, at which the temperature is constant. In various mines, borings, and artesian wells, the temperature has been found to increase about 1° Fahr. for every 60 or 65 feet of descent. In some carefully conducted experiments during the sinking of Dukinfield Deep Mine (one of the deepest pits in this country), it was found that a mean increase of about 1° in 71 feet occurred. If we take the ratio thus indicated, and assume it to extend to much greater depths, we should reach at two and a half miles from the surface-strata at the temperature of boiling water; and at depths of about fifty or sixty miles the temperature would be sufficient to melt, under the ordinary pressure of the atmosphere, the hardest rocks. Reasoning from these facts, it would appear that the mass of the globe, at no great depth, must be in a fluid state. But this deduction requires to be modified by other considerations, namely, the influence of pressure on the fusing-point, and the relative conductivity of the rocks which form the earth's crust. To solve these questions a series of important experiments were instituted by Mr. Hopkins, in the prosecution of which Dr. Joule and myself took part; and after a long and laborious investigation, it was found that the temperature of fluidity increased about 1° Fahr. for every 500 lbs. pressure, in the case of spermaceti, bees-wax, and other similar substances. However, on extending these experiments to less compressible substances, such as tin and barytes, a similar increase was not observed. But these series of experiments has been unavoidably interrupted; nor is the series on the conductivity of rocks entirely finished. Until they have been completed by Mr. Hopkins, we can only make a partial use of them in forming an opinion of the thickness of the earth's solid crust. Judging, however, alone from the greater conductivity of the igneous rocks, we may calculate that the thickness cannot possibly be less than nearly three times as great as that calculated in the usual suppositions of the conductive power of the terrestrial mass at enormous depths, being no greater than that of the superficial sedimentary beds. Other modes of investigation which Mr. Hopkins has brought to bear on this question appear to lead to the conclusion that the thickness of the earth's crust is much greater even than that above stated. This would require us to assume that a part of the heat in the crust is due to superficial and external, rather than central causes. This does not bear directly against the doctrine of central heat, but shows that only a part of the increase of temperature observed in mines and deep wells is due to the outward flow of that heat.

Touching those highly interesting branches of science, Botany and Zoology, it may be considered presumptuous in me to offer any remarks. I have, however, not entirely neglected in my earlier days to inform myself of certain portions of natural history, which cannot but be attractive to all who delight in the wonderful beauties of natural objects. How interesting is the organization of animals and plants; how admirably adapted to their different functions and spheres of life! They want nothing, yet have nothing superfluous. Every organ is adapted perfectly to its functions; and the researches of Owen, Agassiz, Darwin, Hooker, Daubeny, Babington, and Jardine fully illustrate the perfection of the animal and vegetable economy of nature.

Two other important branches of scientific research, Geography and Ethnology, have for some years been united, in this Association, in one Section, and that probably the most attractive and popular of them all. We are much indebted to Sir Roderick Murchison, among other Members of the Association, for its continued prosperity, and the high position it has attained in public estimation. The spirit of enterprise, courage, and perseverence displayed by our travellers in all parts of the world have been powerfully stimulated and well supported by the Geographical Society; and the prominence and rapid publicity given to discoveries by that body have largely promoted geographical research.

In Physical Geography the late Baron von Humboldt has been one of the largest contributors, and we are chiefly indebted to his personal researches and numerous writings for the elevated position it now holds among the sciences. To Humboldt we owe our knowledge of the physical features of Central and Southern America. To Parry, Sir James Ross, and Scoresby, we are indebted for discoveries in the Arctic and Antarctic regions. Geography has also been advanced by the first voyage of Franklin down the Copper Mine River, and along the inhospitable shores of the Northern Seas, as far as Point Turn Again; as also by that ill-fated expedition in search of a north-west passage; followed by others in search of the unfortunate men who perished in their attempt to reach those ice-bound regions, so often stimulated by the untiring energy of a high-minded woman. In addition to these, the discoveries of Dr. Livingstone in Africa have opened to us a wide field of future enterprise along the banks of the Zambesi and its tributaries. To these we may add the explorations of Captain Burton in the same continent; and those also by Captain Speke and Captain Grant, of a hitherto unknown region, in which it has been suggested that the White Nile has its source, flowing from one of two immense lakes, upwards of 300 miles long by 100 broad, and situated at an elevation of 4000 feet above the sea. To these remarkable discoveries I ought to add an honourable mention of the sagacious and perilous exploration of Central and Northern Australia by Mr. M'Dougall Stuart.

Having glanced, however imperfectly, at some of the most important branches of science which engage the attention of Members of this Association, I would now invite attention to the mechanical sciences, with which I am more familiarly acquainted. They may be divided into Theoretical Mechanics and Dynamics, comprising the conditions of equilibrium and the laws of motion; and Applied Mechanics, relating to the construction of machines. I have already observed that practice and theory are twin sisters, and must work together to ensure a steady progress in mechanical art. Let us then maintain this union as the best and safest basis of national progress, and, moreover, let us recognize it as one of the distinctive aims of the annual reunions of this Association.

During the last century, the science of Applied Mechanics has made strides which astonish us by their magnitude; but even these, it may reasonably be hoped, are but the promise of future and more wonderful enlargements. I therefore propose to offer a succinct history of these improvements, as an instance of the influence of scientific progress on the well-being of society. I shall take in review the three chief aids which engineering science has afforded to national progress, namely, canals, steam-navigation, and railways; each of which has promoted an incalculable extension of the industrial resources of the country.

One hundred years ago, the only means for the conveyance of inland merchandize were the pack-horses and waggons on the then imperfect highways. It was reserved for Brindley, Smeaton, and others to introduce a system of canals, which opened up facilities for an interchange of commodities at a cheap rate over almost every part of the country. The impetus given to industrial operations by this new system of conveyance induced capitalists to embark in trade, in mining, and in the extension of manufactures in almost every district. These improvements continued for a series of years, until the whole country was intersected by canals requisite to meet the demands of a greatly extended industry. But canals, however well adapted for the transport of minerals and merchandise, were less suited for the conveyance of passengers. The speed of the canal-boats seldom exceeded from two and a half to three miles an hour; and in addition to this, the projectors of canals sometimes sought to take an unfair advantage of the Act of Parliament, which fixed the tariff at so much per ton per mile, by adopting circuitous routes, under the erroneous impression that mileage was a consideration of great importance to the success of such undertakings. It is in consequence of short-sighted views and imperfect legislation that we inherit the numerous curves and distortions of our canal system.

These defects in construction rendered canals almost useless for the conveyance of passengers, and led to the improvement of the common roads and the system of stage coaches; so that before the year 1830 the chief public highways of the country had attained a remarkable smoothness and perfection, and the lightness of our carriages and the celerity with which they were driven still excites the admiration of those who remember them. These days of an efficiently worked system, which tasked the power and speed of the horse to the utmost, have now been succeeded by changes more wonderful than any that previously occurred in the history of the human race.

Scarcely had the canal system been fully developed when a new means of propulsion was adopted, namely, steam. I need not recount to you the enterprise, skill, and labour that have been exerted in connexion with steam navigation. You have seen its results on every river and every sea; results we owe to the fruitful minds of Miller, Symington, Fulton, and Henry Bell, who were the pioneers in the great march of progress.

Viewing the past, with a knowledge of the present and a prospect of the future, it is difficult to estimate sufficiently the benefits that have been conferred by this application of mechanical science to the purposes of navigation. Power, speed, and certainty of action have been attained on the most gigantic scale. The celerity with which a modern steamer, with a thousand tons of merchandise and some hundreds of human beings on board, cleaves the water and pursues her course, far surpasses the most sanguine expectations of a quarter of a century ago, and indeed almost rivals the speed of the locomotive itself. Previous to 1812 our intercourse with foreign countries and with our colonial possessions depended entirely upon the state of the weather. It was only in favourable seasons that a passage was open, and we had often to wait days, or even a week, before Dublin could be reached from Holyhead. Now this distance of sixty-three miles is accomplished in all weathers in little more than three hours. The passage to America used to occupy six weeks or two months; now it is accomplished in eight or nine days. The passage round the Cape to India is reduced from nearly half a year to less than a third of that time, whilst that country may be reached by the overland route in less than a month. These are a few of the benefits derived from steam-navigation; and as it is yet far from perfect, we may reasonably calculate on still greater advantages in our intercourse with distant nations.

I will not here enter upon the subject of the numerous improvements which have so rapidly advanced the progress of this important service. Suffice it to observe that the paddle-wheel system of propulsion has maintained its superiority over every other method yet adopted for the attainment of speed, as by it the best results are obtained with the least expenditure of power. In ships of war the screw is indispensable, on account of the security it affords to the engines and machinery, from their position in the hold below the water-line, and because of the facility it offers in the use of sails, when the screw is raised from its position in the well to a recess in the stern prepared for that purpose. It is also preferable in ships which require auxiliary power in calms and adverse winds, so as to expedite the voyage and effect a considerable saving upon the freight.

The public mind had scarcely recovered itself from the changes which steam-navigation had caused, and the impulse it had given to commerce, when a new and even more gigantic power of locomotion was inaugurated. Less than a quarter of a century had elapsed since the first steam-boats floated on the waters of the Hudson and the Clyde, when the achievements thence resulting were followed by the application of the same agency to the almost superhuman flight of the locomotive and its attendant train. I well remember the competition at Rainhill in 1830, and the incredulity everywhere evinced at the proposal to run locomotives at twenty miles an hour. Neither George Stephenson himself, nor any one else, had at that time the most distant idea of the capabilities of the railway system. On the contrary, it was generally considered impossible to exceed ten or twelve miles an hour; and our present high velocities, due to high-pressure steam and the tubular system of boilers, have surpassed the most sanguine expectations of engineers. The sagacity of George Stephenson at once seized upon the suggestion of Henry Booth, to employ tubular boilers; and that, united to the blast-pipe, previously known, has been the means of effecting all the wonders we now witness in a system that has done more for the development of practical science and the civilization of man than any discovery since the days of Adam.

From a consideration of the changes which have been effected in the means for the interchange of commodities, I pass on to examine the progress which has been made in their production. And as the steam-engine has been the basis of all our modern manufacturing industry, I shall glance at the steps by which it has been perfected.

Passing over the somewhat mythical fame of the Marquis of Worcester, and the labours of Savery, Beighton, and Newcomen, we come at once to discuss the state of mechanical art at the time when James Watt brought his gigantic powers to the improvement of the steam-engine. At that time the tools were of the rudest construction, nearly everything being done by hand, and, in consequence, wood was much more extensively employed than iron. Under these circumstances Watt invented separate condensation, rendered the engine double-acting, and converted its rectilinear motion into a circular one suitable for the purposes of manufacture. But the discovery at first made little way; the public did not understand it; and a series of years elapsed before the difficulties, commercial and mechanical, which opposed its application, could be overcome. When the certainty of success had been demonstrated, Watt was harassed by infringements of his patent, and law-suits for the maintenance of his rights. Inventors and pretended inventors set up claims, and entered into combination with manufacturers, miners, and others, to destroy the patent, and deprive him of the just fruits of his labour and genius. Such is the selfish heartlessness of mankind in dealing with discoveries not their own, but from which they expect to derive benefit.

The steam-engine, since it was introduced by Watt, has changed our habits in almost every condition of life. Things which were luxuries have become necessaries; and it has given to the poor man, in all countries in which it exists, a degree of comfort and independence, and a participation in intellectual culture unknown before its introduction. It has increased our manufactures tenfold, and has lessened the barriers which time and space interpose. It ploughs the land, and winnows and grinds the corn. It spins and weaves our textile fabrics. In mining it pumps, winds, and crushes the ores. It performs these things with powers so great and so energetic as to astonish us at their immensity, whilst they are at the same time perfectly docile, and completely under human control.

In war it furnishes the means of aggression, as in peace it affords the bonds of conciliation; and, in fact, places within reach a power which, properly applied, produces harmony and goodwill among men, and leads to the happiest results in every condition of human existence. We may, therefore, well be proud of the honour conferred on this country as the cradle of its origin, and as having fostered its development from its earliest applications to its present high state of perfection.

I cannot conclude this notice of the steam-engine without observing the changes it is destined to effect in the cultivation of the soil. It is but a short time since it was thought inapplicable to agricultural purposes, from its great weight and expense. But more recent experience has proved this to be a mistake, and already in most districts we find that it has been pressed into the service of the farm. The small locomotive, mounted on a frame with four wheels, travels from village to village with its attendant, the thrashing-machine, performing the operations of thrashing, winnowing, and cleaning at less than one-half the cost by the old and tedious process of hand labour. Its application to ploughing and tillage on a large scale is, in my opinion, still in its infancy, and I doubt not that many Members of this Association will live to see the steam-plough in operation over the whole length and breadth of the land. Much has to be done before this important change can be successfully accomplished; but, with the aid of the agri-culturist preparing the land so as to meet the requirements of steam-machinery, we may reasonably look forward to a new era in the cultivation of the soil.

The extraordinary developments of practical science in our system of textile manufacture are, however, not entirely due to the steam-engine, although they are now in a great measure dependent on it. The machinery of these manufactures had its origin before the steam-engine had been applied, except for mining purposes; and the inventions of Arkwright, Hargreaves, and Crompton were not conceived under the impression that steam would be their moving power. On the contrary, they depended upon water; and the cotton-machinery of this district had attained considerable perfection before steam came to the aid of the manufacturer, and ultimately enabled him to increase the production to its present enormous extent.

I shall not attempt a description of the machinery of the textile manufactures, because ocular inspection will be far more acceptable. I can only refer you to a list of establishments in which you may examine their operations on a large scale, and which I earnestly recommend to your attention. I may, however, advert to a few of the improvements which have marked the progress of the manufacturing system in this country.

When Arkwright patented his water-frames in 1767, the annual consumption of cotton was about four million pounds weight. Now it is one thousand two hundred million pounds weight,—three hundred times as much. Within half a century the number of spindles at work, spinning cotton alone, has increased tenfold; whilst, by superior mechanism, each spindle produces fifty per cent. more yarn than on the old system. Hence the importance to which the cotton trade has risen, equalling at the present time the whole revenue of the three kingdoms, or £70,000,000 sterling per annum. As late as 1820 the power-loom was not in existence, now it produces about fourteen million yards of cloth, or, in more familiar terms, nearly eight thousand miles of cloth per diem. I give these numbers to show the immense power of production of this country, and to afford some conception of the number and quality of the machines which effect such wonderful results.

Mule-spinning was introduced by Crompton, in 1787, with about twenty spindles to each machine. The powers of the machine were, however, rapidly increased; and now it has been so perfected that two thousand or even three thousand spindles are directed by a single person. At first the winding on, or forming the shape of the cop, was performed by hand; but this has been superseded by rendering the machine automatic, so that it now performs the whole operation of drawing, stretching, and twisting the thread, and winding it on to the exact form, ready for the reel or shuttle as may be required. These, and other improvements in carding, roving, combing, spinning, and weaving have established in this country an entirely new system of industry; it has given employment to greatly increased numbers, and a more intelligent class of work-people.

Similarly important improvements have been applied to the machinery employed in the manufacture of silk, flax, and wool; and we have only to watch the processes in these different departments to be convinced that they owe much to the development of the cotton manufacture. In the manufacture of worsted, the spinning jenny was not employed at Bradford until 1790, nor the power loom until about 1825. The production of fancy or mixed goods from alpaca and mohair wool, introduced to this country in 1836, is perhaps the most striking example of a new creation in the art of manufacture, and is chiefly due to Mr. Titus Salt, in whose immense palace of industry, at Saltaire, it may be seen in the greatest perfection. In flax machinery the late Sir Peter Fairbairn was one of the most successful inventors, and his improvements have contributed to the rapid extension of this manufacture.

I might greatly extend this description of our manufacturing industry, but I must for the present be brief, in order to point out the dependence of all these improvements on the iron and coal so widely distributed amongst the mineral treasures of our island. We are highly favoured in the abundance of these minerals, deposited with an unsparing hand by the great Author of nature, under so slight a covering as to bring them within reach of the miner's art. To them we owe our present high state of perfection in the useful arts; and to their extended application we may safely attribute our national progress and wealth. So that, looking to the many blessings which we daily and hourly receive from these sources alone, we are impressed with devotional feelings of gratitude to the Almighty for the manifold bounties He has bestowed upon us.

Previously to the inventions of Henry Cort, the manufacture of wrought iron was of the most crude and primitive description. A hearth and a pair of bellows was all that was employed. But since the introduction of puddling, the iron-masters have increased the production to an extraordinary extent, down to the present time, when processes for the direct conversion of wrought iron on a large scale are being attempted. A consecutive series of chemical researches into the different processes, from the calcining of the ore to the production of the bar, carried on by Dr. Percy and others, has led to a revolution in the manufacture of iron; and although it is at the present moment in a state of transition, it nevertheless requires no very great discernment to perceive that steel and iron of any required tenacity will be made in the same furnace, with a facility and certainty never before attained. This has been effected, to some extent, by improvements in puddling; but the process of Mr. Bessemer, first made known at the meetings of this Association at Cheltenham, affords the highest promise of certainty and perfection in the operation of converting the melted pig direct into steel or iron, and is likely to lead to the most important developments in this manufacture. These improvements in the production of the material must, in their turn, stimulate its application on a larger scale and lead to new constructions.

In iron shipbuilding, an immense field is open before us. Our wooden walls have, to all appearance, seen their last days; and as one of the early pioneers in iron construction, as applied to shipbuilding, I am highly gratified to witness a change of opinion that augurs well for the security of the liberties of the country. From the commencement of iron shipbuilding in 1830 to the present time, there could be only one opinion amongst those best acquainted with the subject, namely, that iron must eventually supersede timber in every form of naval construction. The large ocean steamers, the 'Himalaya,' the 'Persia,' and the 'Great Eastern,' abundantly show what can be done with iron; and we have only to look at the new system of casing ships with armour-plates, to be convinced that we can no longer build wooden vessels of war with safety to our naval superiority and the best interests of the country. I give no opinion as to the details of the reconstruction of the navy,—that is reserved for another place,—but I may state that I am fully persuaded that the whole of our ships of war must be rebuilt of iron, and defended with iron armour calculated to resist projectiles of the heaviest description at high velocities.

In the early stages of iron shipbuilding, I believe I was the first to show, by a long series of experiments, the superiority of wrought iron over every other description of material in security and strength, when judiciously applied in the construction of ships of every class. Other considerations, however, affect the question of vessels of war; and although numerous experiments were made, yet none of the targets were on a scale sufficient to resist more than a six-pounder shot. It was reserved for our scientific neighbours, the French, to introduce thick iron plates as a defensive armour for ships. The success which has attended the adoption of this new system of defence affords the prospect of invulnerable ships of war, and hence the desire of the Government to remodel the navy on an entirely new principle of construction, in order that we may retain its superiority as the great bulwarks of the nation. A committee has been appointed by the War Office and the Admiralty for the purpose of carrying out a scientific investigation of the subject, so as to determine, first, the best description of material to resist projectiles; secondly, the best method of fastening and applying that material to the sides of ships and land fortifications; and, lastly, the thickness necessary to resist the different descriptions of ordnance.

It is asserted, probably with truth, that whatever thickness of plates are adopted for casing ships, guns will be constructed capable of destroying them. But their destruction will even then be a work of time; and I believe, from what I have seen in recent experiments, that with proper armour it will require, not only the most powerful ordnance, but also a great concentration of fire, before fracture will ensue. If this be the case, a well-constructed iron ship, covered with sound plates of the proper thickness, firmly attached to its sides, will, for a considerable time, resist the heaviest guns which can be brought to bear against it, and be practically shot-proof. But our present means are inadequate for the production of large masses of iron, and we may trust that, with new tools and machinery, and the skill, energy, and perseverance of our manufacturers, every difficulty will be overcome, and armour-plates produced which will resist the heaviest existing ordnance.

The rifling of heavy ordnance, the introduction of wrought iron, and the new principle of construction with strained hoops, have given to all countries the means of increasing enormously the destructive power of their ordnance. One of the results of this introduction of wrought iron, and correct principles of manufacture, is the reduction of the weight of the new guns to about two-thirds the weight of the older cast-iron ordnance. Hence follows the facility with which guns of much greater power can be worked, whilst the range and precision of fire are at the same time increased. But these improvements cannot be confined to ourselves. Other nations are increasing the power and range of their artillery in a similar degree, and the energies of the nation must therefore be directed to maintain the superiority of our navy in armour as well as in armament.

We have already seen a new era in the history of the construction of bridges, resulting from the use of iron; and we have only to examine those of the tubular form over the Conway and Menai Straits to be convinced of the durability, strength, and lightness of tubular constructions applied to the support of railways or common roads, in spans which, ten years ago, were considered beyond the reach of human skill. When it is considered that stone bridges do not exceed 200 feet in span, nor cast-iron bridges 250 feet, we can estimate the progress which has been made in crossing rivers 400 or 500 feet in width, without any support at the middle of the stream. Even spans, greatly in excess of this, may be bridged over with safety, provided we do not exceed 1800 to 2000 feet, when the structure would be destroyed by its own weight.

It is to the exactitude and accuracy of our machine tools that our machinery of the present time owes its smoothness of motion and certainty of action. When I first entered this city, the whole of the machinery was executed by hand. There were neither planing, slotting, nor shaping machines, and, with the exception of very imperfect lathes and a few drills, the preparatory operations of construction were effected entirely by the hands of the workmen. Now everything is done by machine tools, with a degree of accuracy which the unaided hand could never accomplish. The automaton, or self-acting machine tool, has within itself an almost creative power; in fact, so great are its powers of adaptation, that there is no operation of the human hand that it does not imitate. For many of these improvements, the country is indebted to the genius of our townsmen, Mr. Richard Roberts and Mr. Joseph Whitworth. The importance of these constructive machines is, moreover, strikingly exemplified in the Government works at Woolwich and Enfield Lock, chiefly arranged under the direction of Mr. Anderson, the present inspector of machinery, to whose skill and ingenuity the country is greatly indebted for the efficient state of those great arsenals.

Amongst the changes which have largely contributed to the comfort and enjoyment of life, are the improvements in the sanitary condition of towns. These belong, probably, to the province of social rather than mechanical science; but I cannot omit noticing some of the great works that have of late years been constructed for the supply of water, and for the drainage of towns. In former days, ten gallons of water to each person per day was considered an ample allowance. Now thirty gallons is much nearer the rate of consumption. I may instance the water-works of this city and of Liverpool, each of which yield a supply of from twenty to thirty gallons of water to each inhabitant. In the former case, the water is collected from the Cheshire and Derbyshire Hills, and, after being conveyed in tunnels and aqueducts a distance of ten miles to a reservoir, where it is strained and purified, it is ultimately taken a further distance of eight miles in pipes, in a perfectly pure state, ready for distribution. The greatest undertaking of this kind, however, yet accomplished, is that by which the pure waters of Loch Katrine are distributed to the city of Glasgow. This work, recently completed by Mr. Bateman, who was also the constructor of the water-works of this city, is of the most gigantic character, the water being conveyed in a covered tunnel a distance of twenty-seven miles, through an almost impassable country, to the service reservoir, about eight miles from Glasgow. By this means forty million gallons of water per day are conveyed through the hills which flank Ben Lomond, and after traversing the sides of Loch Chon and Loch Aird, are finally discharged into the Mugdock basin, where the water is impounded for distribution. We may reasonably look forward to an extension of similar benefits to the metropolis, by the same engineer, whose energies are now directed to an examination of the pure fountains of Wales, from whence the future supply of water to the great city is likely to be derived. A work of so gigantic a character may be looked upon as problematical; but when it is known that six or seven millions of money would be sufficient for its execution, I can see no reason why an undertaking of so much consequence to the health of London should not ultimately be accomplished.

In leaving this subject, I cannot refrain from an expression of deep regret at the loss which science has sustained through the death of one of our Vice-Presidents, the late Professor Hodgkinson. For a long series of years he and I worked together in the same field of scientific research, and our labours are recorded in the Transactions of this and other Associations.

To Mr. Hodgkinson we owe the determination of the true form of cast-iron beams, or section of greatest strength; the law of the elasticity of iron under tensile and compressive forces; and the laws of resistance of columns to compression. I look back to the days of our joint labour with unalloyed pleasure and satisfaction.

I regret to say that another of our Vice-Presidents, my friend Mr. Joseph Whitworth, is unable to be present with us through serious, but I hope not dangerous, illness. To Mr. Whitworth mechanical science is indebted for some of the most accurate and delicate pieces of mechanism ever executed; and the exactitude he has introduced into every mechanical operation will long continue to be the admiration of posterity. His system of screw-threads and gauges is now in general use throughout Europe. We owe to him a machine for measuring with accuracy to the millionth of an inch, employed in the production of standard gauges; and his laborious and interesting experiments on rifled ordnance have resulted in the production of a rifled small-arm and gun which have never been surpassed for range and precision of fire. It is with pain that I have to refer to the cause which deprives me of his presence and support at this meeting.

A brief allusion must be made to that marvellous discovery which has given to the present generation the power to turn the spark of heaven to the uses of speech—to transmit along the slender wire for a thousand miles a current of electricity that renders intelligible words and thoughts. This wonderful discovery, so familiar to us, and so useful in our communications to every part of the globe, we owe to Wheatstone, Thomson, De la Rive, and others. In land-telegraphy the chief difficulties have been surmounted, but in submarine telegraphy much remains to be accomplished. Failures have been repeated so often as to call for a Commission on the part of the Government to inquire into the causes, and the best means of overcoming the difficulties which present themselves. I had the honour to serve on that Commission, and I believe that from the report, and mass of evidence and experimental research accumulated, the public will derive very important information. It is well known that three conditions are essential to success in the construction of ocean telegraphs—perfect insulation, external protection, and appropriate apparatus for laying the cable safely on its ocean bed. That we are far from having succeeded in fulfilling these conditions is evident from the fact that out of twelve thousand miles of submarine cable which have been laid since 1851, only three thousand miles are actually in working order; so that three-fourths may be considered as a failure and loss to the country. The insulators hitherto employed are subject to deterioration from mechanical violence, from chemical decomposition or decay, and from the absorption of water; but the last circumstance does not appear to influence seriously the durability of cables. Electrically, india-rubber possesses high advantages, and, next to it, Wray's compound and pure gutta-percha far surpass the commercial gutta-percha hitherto employed; but it remains to be seen whether the mechanical and commercial difficulties in the employment of these new materials can be successfully overcome. The external protecting covering is still a subject of anxious consideration. The objections to iron wire are its weight and liability to corrosion. Hemp has been substituted, but at present with no satisfactory result. All these difficulties, together with those connected with the coiling and paying out of the cable, will no doubt yield to careful experiment and the employment of proper instruments in its construction and its final deposit on the bed of the ocean.

Irrespective of inland and international telegraphy, a new system of communication has been introduced by Professor Wheatstone, whereby intercourse can be carried on between private families, public offices, and the works of merchants and manufacturers. This application of electric currents cannot be too highly appreciated, from its great efficiency and comparatively small expense. To show to what an extent this improvement has been carried, I may state that one thousand wires, in a perfect state of insulation, may be formed into a rope not exceeding half an inch in diameter.

I must not sit down without directing attention to a subject of deep importance to all classes, namely, the amount of protection inventors should receive from the laws of the country. It is the opinion of many that patent laws are injurious rather than beneficial, and that no legal protection of this kind ought to be granted; in fact, that a free trade in inventions, as in everything else, should be established. I confess I am not of that opinion. Doubtless there are abuses in the working of the patent law as it at present exists, and protection is often granted to pirates and impostors, to the detriment of real inventors. This, however, does not contravene the principle of protection, but rather calls for reform and amendment. It is asserted by those who have done the least to benefit their country by inventions, that a monopoly is injurious, and that if the patent laws are defended, it should be, not on the ground of their benefit to the inventor, but on that of their utility to the nation. I believe this to be a dangerous doctrine, and I hope it will never be acted upon. I cannot see the right of the nation to appropriate the labours of a lifetime, without awarding remuneration. The nation, in this case, receives a benefit; and assuredly the labourer is worthy of his hire. I am no friend of monopoly, but neither am I a friend of injustice; and I think that before the public are benefited by an invention, the inventor should be rewarded either by a fourteen years' monopoly or in some other way. Our patent laws are defective, so far as they protect pretended inventions; but they are essential to the best interests of the State in stimulating the exertions of a class of eminent men, such as Arkwright, Watt, and Crompton, whose inventions have entailed upon all countries invaluable benefits, and have done honour to the human race. To this Association is committed the task of correcting the abuses of the present system, and establishing such legal provisions as shall deal out equal justice to the inventor and the nation at large.

I must not forget that we owe very much to an entirely new and most attractive method of diffusing knowledge, admirably exemplified in the Great Exhibition of 1851, and its successors in France, Ireland, and America. Most of us remember the gems of art which were accumulated in this city during the summer of 1857, and the wonderful results they produced on all classes of the community. The improvement of taste and the increase of practical knowledge which followed these exhibitions have been deeply felt; and hence the prospects which are now opening before us in regard to the Exhibition of the next year cannot be too highly appreciated. That Exhibition will embrace the whole circle of the sciences, and is likely to elevate the general culture of the public to a higher standard than we have ever before attained. There will be unfolded almost every known production of art, every ingenious contrivance in machinery, and the results of discoveries in science from the earliest period. The Fine Arts, which constituted no part of the Exhibition of 1851, and which were only partially represented at Paris and Dublin, will be illustrated by new creations from the most distinguished masters of the modern school. Looking forwards, I venture to hope for a great success and a further development of the principle advocated by this Association—the union of science and art.

In conclusion, my apologies are due to you for the length of this address, and I thank you sincerely for the patient attention with which you have listened to the remarks I have had the honour to lay before you. As the President of the British Association, I feel that, far beyond the consideration of merely personal qualifications, my election was intended as a compliment to practical science, and to this great and influential metropolis of manufacture, where those who cultivate the theory of science may witness, on its grandest scale, its application to the industrial arts. As a citizen of Manchester, I venture to assure the Association that its intentions are appreciated; and to its members, as well as to the strangers who have been attracted here by this meeting, I offer a most cordial welcome.

REPORTS

ON

THE STATE OF SCIENCE.

Report on Observations of Luminous Meteors, 1860–61. *By a Committee, consisting of* James Glaisher, *Esq., F.R.S., of the Royal Observatory, Greenwich, Secretary to the British Meteorological Society, &c.;* J. H. Gladstone, *Esq., Ph.D., F.R.S. &c.;* R. P. Greg, *Esq., F.G.S. &c.; and* E. J. Lowe, *Esq., F.R.A.S., M.B.M.S. &c.*

The Committee, in presenting this report upon the Luminous Meteors of the past year, feel that the arrangement for collecting this information is far from perfect, as for the most part the number of observers, Members of the Association, who have sent observations are very few indeed.

During the entire year 1860 the number of meteors were few, and the sky during the nights of both the August and November epochs was generally overcast over the whole country, and scarcely any meteors were seen.

In the August just passed, the sky for the most part was clear, and many meteors were observed.

It was stated in the Report for last year, that the remarkable meteor of March 10, 1860, must have been seen by many persons, and it seems to have been so, but no observations were taken by them of elevation, direction, &c.; and we are not in possession, even now, of sufficient information upon which to base calculations.

In the Catalogue of Meteors observed this year, of one alone have accounts by three observers been received, that of July 16, 1861, as seen by the Duke of Argyll, at Kensington; Mr. Frost, at the Isle of Wight; and Mr. Howe, at Greenwich: the three observers agree as to the place of its origin, viz. near α Lyræ, but Mr. Howe says it moved towards the N.E., whilst Mr. Frost says its motion was towards the S.W., just in opposite directions to each other*. Another meteor, that of August 6, at 11.15, was seen by two observers; the one at Manchester, the other near Macclesfield, but in neither case are sufficient data recorded.

The Committee regret that but one account of all the remaining meteors in the catalogue has been received, and nothing can therefore be added to the observations themselves.

* This was also probably the one seen at Tunbridge Wells, at Darlington in Yorkshire, and at Namur in Flanders, and of which an approximate orbit has been calculated by Mr. Alexander S. Herschell. (See Appendix, No. 3.)

They would earnestly press upon the Members of the British Association the necessity of more complete and numerous observations, noting the times of appearance and disappearance, by a watch regulated to railway time, or whose error from railway time is known nearly; the size, colour, and general description of the meteor, and its place among the stars at its first appearance and at its last appearance. If these particulars were received from three or four observers, separated from each other by some little distance, sufficient information would be furnished to determine in many cases the

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1849. Aug. 11	h m Midnight	Globular; 12 times the size of Venus when seen in her full splendour.	Bright blue ...	....	30 seconds ....
1859. Oct. 25	7 15 p.m.	Very large	Intensely white.	Burst into fragments of a red colour.	8 seconds ....
1860. Mar. 10	9 0 p.m.	= $\frac{2}{3}$ moon	Purple	....	....
10	9 0 p.m.	Brilliant meteor	....	....	....
10	9 0 p.m.	Much the same as at Bradford.	....	....	....
10	9 0 p.m.	....	Scarlet before bursting, green afterwards.	....	....
10	9 0 p.m.	Brilliant	Reddish	....	....
July 5	10 20 p.m.	= 1st mag. *	Blue	Streak left	Rapid ....
6	From 10 till 11 p.m.	Six small meteors from 2nd to 4th mag.	Colourless ...	Slight trains	Rapid ....
7	10 25 p.m.	= Venus, and as bright.	Bluish	Train	1 second; moved over 20° of sky.
7	From 10 p.m. till midnight.	From 2nd mag. * to = Venus.	Blue	Trains	Rapid ....
8	In the two hours preceding 2 a.m.	From 3rd mag. * to = Venus.	Blue or colourless.	Trains long	Rapid; duration from 0·1 sec. to $1\frac{1}{2}$ sec.
10	11 15 p.m.	Twice the size of Venus, and brighter.	Blue	Left a streak in the sky which lingered after the meteor had vanished.	Slow; duration second.

distance of the meteor from the earth, its path, size, velocity, &c., and thus render these reports far more valuable than they are at present. The following Catalogue contains a list of all the meteors, accounts of which have reached the Members of the Committee, arranged in their order of occurrence.

In the Appendix following the Catalogue are abstracts from some of the most important papers which have appeared, during this year, connected with this branch of science.

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
In the S.; burst into fragments with a great flash, followed by detonation.	....	Siberia	J. Atkinson	MS. communication.
S.E. to N.W.	Light as day	Athlone and Holyhead.	....	See Appendix No. 1.
In the westerly part of the heavens; no noise.	....	Bradford.	Collected by Mr. Greg.	
....	....	Alderly Edge, Cheshire.		
....	....	Newport, in Salop.		
Fell, inclining in an arc of 15°..	....	Leeds.		
Moved downwards towards W.S.W.	....	Blackburn.		
From Polaris towards α Ursæ Majoris.	....	Plymouth.........	E. J. Lowe	MS. communication.
In Ursa Major and Ursa Minor	From direction of Cassiopeia.	H. M. S. S. 'Himalaya,' Plymouth Breakwater.	Id.	Ibid.
From the zenith towards N.W. horizon.	....	H. M. S. S. 'Himalaya,' Bay of Biscay.	Id.	Ibid.
In northern heavens	Counted 17 fine meteors. Lightning over France.	Ibid	Id.	Ibid.
In northern heavens	Counted 24 meteors, some very brilliant. Frequent lightning over France.	Ibid	Id.	Ibid.
Fell from direction of zenith, almost across Mars.	Very fine and warm. Several very small meteors seen, but not nearly so many as on the evening of 4th and early morning of 5th instant.	Fuente del Mer, near Santander, North Spain.	Id.	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1860. July 13	h m 10 10 p.m.	= 1st mag. *, and twice as bright.	Intensely blue	No separate streak; disappeared instantaneously.	Rapid ....
15 or 16	11 0 p.m.	About the size of the full moon; oblong.	....	Long tail, somewhat resembling a rocket.	....
25	From 10 p.m. till 1 a.m. of 26th.	Small	Colourless ...	....	Rapid ....
29	....	Like a dark perpendicular line.	....	....	....
Aug. 4	9 28 p.m.	= 2nd mag. *	....	None	Instantaneous ......
7	0 16 a.m.	= 2nd mag. *	Blue..........	....	About 1 second ...
20	9 45 p.m.	....	Blue, enveloped in a white mist.	Red sparks	Slow............
Oct. 13	9 0 p.m.	About ½ the size of the moon.	White	Tail like a rocket, and with reddish sparks.	3 or 4 seconds......
15	1 22 a.m.	About the size of Venus.	....	Light train	0·5 second ....
20	6 45 p.m.	Splendid meteor	Brilliant	Long streak...............	5 or 6 seconds.....

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
From Vega towards west horizon, moving over 8° of sky. Several very small ones, less than 6th magnitude.	Very small meteors could be seen, owing to the great purity of the air at this great elevation. The stars brighter than I ever saw them before.	Reinosa (amongst the Spanish mountains).	E. J. Lowe	MS. communication.
Fell from about 30 degrees S.W. of the horizon, passing a few degrees S. of Arcturus.	The state of the atmosphere was very electrical; several electric clouds were seen traversing the valley of the Spey.	Banff.		
In various directions	A number of meteors, all small.	Santander	E. J. Lowe	Ibid.
Fell from the zenith towards the earth.	When a few yards from the earth there was a sudden blaze, as of a rocket bursting, and soon after there was a sound as of shot falling upon the leaves, but no fragments have been found.	Little Bridy......	H. S. Eaton......	Ibid.
From a few degrees N. of Arcturus, through 15° of space.	....	Craven Hill, London.	J. H. Gladstone..	Ibid.
From about the middle of the constellation Draco, to within a degree of ε Bootæ.	....	Greenwich Park.	H. S. Eaton......	Ibid.
In the N.E.; from about 90° to 40°.	When about 20° from the zenith, it burst into two pieces, which travelled parallel to each other for the remainder of the course.	New York	....	Ibid.
In the southern sky; travelled E. and W. for about 25° or 30°.	Cast shadows, and finally burst into sparks or fragments at about an elevation of 40°. Seemed very near; could hear no report.	Dover	R. P. Greg	Ibid.
In the N.W., at an elevation of 75°; disappeared in the W. at an elevation of 30°.	....	Greenwich	J. MacDonald ...	Ibid.
From κ Persei to α Ursæ Majoris for about two-thirds of the distance.	Atmosphere very clear; bright moon; day before the first quarter.	Ibid	W. T. Lynn, J. Howe.	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1860. Oct. 20	h m 10 0 p.m.	= 2nd mag. *	Colourless ...	None	2 seconds...........
Nov. 1	8 30 p.m.	Larger than Mars ...	Yellowish; the fragments red, blue, and yellow.	Rocket-like discharges, and a streak left behind.	3 seconds ....
1	8 35 p.m.	Splendid meteor	About the colour and brightness of Arcturus.	....	....
2	7 3 p.m.	= 2nd mag. *	Blue............	Streak left	Rapid ....
7	8 46 p.m.	Larger than 1st mag.*	Blue............	Detached sparks in its track.	Rapid ....
15	10 23 p.m.	About 2nd mag. * ...	Bluish	None	Rapid ....
20	8 55 p.m.	Larger than 1st mag.*	Blue............	....	Rapid ....
Dec. 11	6 25 p.m.	Splendid meteor	....	....	1 second ....
15	10 15 p.m.	= 1st mag. *	....	....	....
18	6 p.m. till 10 p.m.	....	....	....	Rapid ....
20	10 25 p.m.	2nd mag. *	....	A spark	....
1861. Jan. 5	....	Splendid meteor	....	....	....
6	2 20 a.m.	= 2nd mag. *	Bluish	As a spark	Instantaneous .....

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
In N., starting at an altitude of 45°, falling at an angle of 45° towards N. horizon, and terminating at Ursa Major.	This meteor appeared, disappeared, and reappeared four different times during its progress. Many other meteors during the evening.	Highfield House Observatory.	E. J. Lowe	MS. communication.
Moved from S. to W.; starting from below γ Pegasi; moving downwards towards W., and when about η Aquarii, burst and threw down fragments like the discharge of a rocket, the fragments falling perpendicularly down; then moved on to ε Aquarii, when it burst a second time, and threw down perpendicularly; then moved on about 3°, and instantly vanished.	The pauses in motion were very apparent. The meteor moving at an angle of 45°, along which a streak was left; the fragments, however, fell perpendicularly down.	Beeston Observatory.	Id.	Ibid.
In the N.W., passing N. parallel to the meridian for about 25° or 30°.	The sky clear, and moon very bright.	Swanage	Rev. F. C. Penrose	Ibid.
From altitude of 65° due W.; fell perpendicularly down.	Brilliant Aurora Borealis.	Observatory, Beeston.	E. J. Lowe	Ibid.
From β Ursæ Majoris, almost horizontally towards the E., inclining downwards 2°.	....	Ibid...............	Id.	Ibid.
Fell down perpendicularly from a point a little above Polaris to within 15° of the N. horizon.	....	Royal Observatory.	W. C. Nash	Ibid.
Fell 10° amongst cloud, from altitude of 30° in S.S.E., moving towards S.	A fine meteor	Observatory, Beeston.	E. J. Lowe	Ibid.
Fell from the zenith towards the S.W.	Visible through Nimbus cloud, rain falling at the time.	Leyton, Essex...	H. S. Eaton......	Ibid.
In N.W., at about 45°.	Disappeared and reappeared four times. Aurora Borealis.	Observatory, Beeston.	E. J. Lowe	Ibid.
....	Several meteors ...	Ibid...............	Id.	Ibid.
In W.N.W. at about 45°	As a spark. It appeared, disappeared, and reappeared several times.	Ibid...............	Id.	Ibid.
Passed over the Island, and exploded some distance from land with a loud report.	....	Bermuda.		
Shot rapidly across Corona Borealis, at an angle of 45° towards N. horizon.	Apparently near the earth.	Highfield House Observatory.	E. J. Lowe	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1861. Jan. 7	h m 7 51 p.m.	Size of Venus	Blue...........	Light train of red sparks...	20 seconds ....
Feb. 11	6 30 p.m.	....	....	....	....
11	8 12 p.m.	Brighter than any of the fixed stars.	Red	None	....
17	4 0 a.m.	....	Deep blue ...	....	2 seconds...........
17	6 28 p.m.	Large	....	....	....
Mar. 4	....	Like a cone, moving base foremost; the light equal to that of melting iron.	....	Tail like a comet............	....
10	8 50 p.m.	= 2nd mag. *	....	None	1 to 2 seconds ...
Apr. 10	10 25 p.m.	Splendid meteor	Brilliant white	Long train of light	Slow ....
12	7 40 p.m.	Splendid meteor, about twice the size of ♃.	....	None	....
May 19	8 45 p.m.	Size of ♃...............	Straw colour...	None	1 second ....
June 30	10 0 p.m.	= 1st mag. *	Blue	Streak long	....
30	Evening.	....	....	....	....
July 3	Midnight, or a few minutes after.	= Jupiter	Straw colour...	None	About 1 second ...

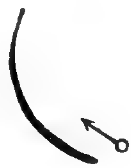
Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
Vhen first seen was very near Mars; disappeared a few degrees above the horizon.	....	Chester	R. L. Jones ...	MS. communication.
[.W., immediately followed by a vivid flash of lightning.	....	Allenheads	T. Bewick	Ibid.
n the W.; fell towards the horizon from the neighbourhood of the Pleiades.	....	Tavistock Place..	Mrs. J. H. Gladstone.	Ibid.
ell from the N.E. about 70°, and disappeared in the E. about 50°.	....	Greenwich	J. MacDonald...	Ibid.
ı due S., at an altitude of 48°.	....	Highfield House.	E. J. Lowe	Ibid.
....	It appeared to come out of a cloud; when it fell to the ground, it ploughed up the earth for a distance of twelve yards.	Ballarat, Australia.		
rom Capella to the Pleiades...	Cloudless	Greenwich	W. C. Nash......	Ibid.
[oving S.W. to N.E., nearly in the zenith, at the rate of 25° in 4 seconds.	It suddenly disappeared as if partially bursting, leaving a beautiful purple fire for 1 or 2 seconds. The course was most distinctly serpentine; several shooting stars seen at the same time, their paths being at right angles to the larger one. Nucleus round, and surrounded in front and on all sides by luminosity, even on the forward part.	Manchester	R. P. Greg	Ibid.
ppeared in the constellation Leo, near Jupiter, passing through Orion, terminating near the Pleiades.	....	Woking, Surrey.		
the S., at an elevation of 60°; disappeared at about 30° behind a clump of trees about half a mile distant.	When at an elevation of about 45°, it disappeared behind a cloud and reappeared at an elevation of 40°.	Greenwich	J. MacDonald ...	Ibid.
ossed Polaris	Peculiar auroral glow-like.	Highfield House.	E. J. Lowe	Ibid.
....	Many fine meteors.	Ibid................	Id.	Ibid.
ll from a few degrees under the head of the comet in a S.W. direction.	....	Greenwich	J. MacDonald ...	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1861. July 7	h m 10 30 p.m.	Large	Brilliant	Sparks emitted during the whole of the course.	....
16	10 50 p.m. approximate time.	= 4 times the size of 1st mag. *.	Yellowish......	Splendid train..............	5 to 6 seconds.....
16	Before 11 p.m.	....	....	None, but one large spark was given off just before it was lost sight of.	....
16	p.m.	Large	....	Burst	11 seconds ....
16	11 33 p.m.	Resembled a signal rocket of large size.	....	A brilliant train	5 minutes ....
16	11 40 p.m.	Magnificent meteor...	Blue	Leaving a thin pencil of light.	20 to 30 seconds.
18	11 30 p.m.	Fine, like a rocket ...	White	....	....
20	9 0 p.m.	2 > Venus	....	....	....
Aug. 6	9 50 p.m.	= 1st mag. * ; a very fine meteor.	Blue	Long and brilliant train...	4 seconds.........
6	11 42 p.m.	Small, but bright ...	....	None	Almost momenta

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
rom near β Ursæ Majoris, in a horizontal direction 12 or 15 degrees.	Distant thunder heard.	Thelwall, near Warrington.	J. Atkinson	MS. communication.
assed from α Lyræ in a N.E. direction to the horizon.	It burst noiselessly about 10° from the horizon.	Greenwich Park.	J. Howe	Ibid.
....	Its extreme brightness, and its rapid and steady motion were singularly striking and beautiful. This meteor gave one, irresistibly the impression of a body moving very near, if not quite within the atmosphere of the earth.	Kensington	Duke of Argyll.	
....	....	Darlington, Yorkshire, and Namur in Flanders.	....	See Appendix No.3.
. the zenith, near α Lyræ, going in a S.W. course ; disappearing a few degrees above the horizon.	A peculiar feature in this train was, that although on its first appearance it was to the eye perfectly straight, it soon became curved in a direction opposite to that in which the wind was blowing; and as it faded, portions of it were drifted in that direction, until they were lost in the brightness of the Milky Way.	Sandown, Isle of Wight.	W. M. Frost.	
shot along the sky from E. to W.	....	....	....	MS. communication.
ot straight down to the horizon from a moderate altitude.	The moon was shining at the time, and nearly in the position of the meteor, viz. W.N.W.	Doe Castle, co. Donegal.	R. P. Greg	Ibid.
rst high up in the air.........	....	Nantwich.		
om the zenith to the E. of α Lyræ; passed to a point a few degrees below β Ursæ Majoris	Fine night	Greenwich	W. C. Nash......	Ibid.
peared between δ Cygni and α Lyræ.	....	Ibid................	Id.	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1861.	h m s				
Aug. 6	11 15 p.m.	= three times the diameter of Venus.	Very pale blue	....	18 to 20 seconds...
6	11 15 p.m.	....	....	....	....
8	10 14 p.m.	....	....	None	Almost momentary
8	10 21 p.m.	= 2nd mag. *.........	Blue	Small train	From 1 second to 2 seconds.
8	10 25 p.m.	Small	....	None	1 second ....
8	10 28 p.m.	= 3rd mag. *	....	None	Very rapid ....
8	10 31 p.m.	Very small	....	None	1 second ....
8	10 32 p.m.	= 2nd mag. *.........	....	Small train	2 seconds.........
8	10 39 p.m.	Very brilliant, much brighter than Capella.	....	Small but very brilliant train.	....
8	10 41 p.m.	Small	....	None	1 second ....
8	10 43 p.m.	Very faint	....	None	....
8	10 46 p.m.	Very fine, = 1st mag.*	....	Leaving a brilliant train of some degrees in length..	2 seconds.........
8	10 47 p.m.	Very small	....	None	Rapid ....
8	10 51 p.m.	Very fine	....	Leaving a train about 20° in length.	2 to 3 seconds......
8	10 53 p.m.	Very fine, = 1st mag. *	....	Train 20° in length.........	2 seconds.........
8	10 59 p.m.	= 1st mag. *	....	No train or sparks	....
8	11 3 p.m.	Very small	....	None	....
9	9 58 30 p.m.	= 1st mag.*.........	Blue.........	Stream of light	Duration 0·8 sec...
9	10 0 30 p.m.	= ♃.........	Blue.........	Long tail.........	Rapid ....
9	10 14 30 p.m.	= 3rd mag.*	Colourless ...	As a spark; no stream of light.	Instantaneous ......
9	10 16 30 p.m.	= 3rd mag.*, and increased to 1st mag.*	Yellow	Streak	Duration 0·1 sec...
9	10 16 p.m.	= 2nd mag.*	....	None	1 second ....
9	10 18 30 p.m.	Small	Yellow	Slight streak	Duration 0·1 sec...

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
n the S.S.E., at an elevation half between the horizon and the zenith.	The night was beautifully clear.	Manchester	R. E. B.	MS. communication.
n the S.S.E., appearing to fall beyond the range of surrounding hills.	....	Prestbury, near Macclesfield.	W. N.	Ibid.
'rom Cygnus to α Aquilæ	Fine clear night ...	Royal Observatory, Greenwich.	J. Howe	Ibid.
Shot upwards through Cassiopeia.	Fine clear night ...	Ibid..............	W. C. Nash	Ibid.
'rom α Andromedæ across α Pegasi.	Fine clear night ...	Ibid..............	Id.	Ibid.
'assed in a westerly direction across Vulpecula.	Fine clear night ...	Ibid..............	Id.	Ibid.
'assed rapidly from μ Cygni to Sagitta.	Fine clear night ...	Ibid..............	Id.	Ibid.
'assed from κ Cygni to Delphinus.	Fine clear night ...	Ibid..............	W. C. Nash and J. Howe.	Ibid.
'ell in a N.E. direction past and near Capella. Its course did not appear longer than 10° or 12°.	....	Ibid..............	W. C. Nash	Ibid.
'assed from Cepheus to Sagitta.	....	Ibid..............	J. Howe	Ibid.
'rom β Draconis to midway between 12 Canum Venaticorum and ι Ursæ Majoris.	....	Ibid..............	Id.	Ibid.
'rom α Lyræ to Cassiopeia ...	....	Ibid..............	Id.	Ibid.
'assed downwards about 10° E. of α Ophiuchi.	....	Ibid..............	W. C. Nash	Ibid.
ppeared near β Draconis and passed to Arcturus.	....	Ibid..............	J. Howe	Ibid.
'rom α Lyræ, passed to the E. of α Coronæ Borealis to β Serpentis.	....	Ibid..............	Id.	Ibid.
'ell perpendicularly from α Coronæ Borealis to the horizon.	....	Ibid..............	W. C. Nash	Ibid.
rom γ Draconis to Polaris ...	....	Ibid..............	J. Howe	Ibid.
Iorizontally from 1° above ξ Ursæ Majoris, coming from the direction of Perseus.	....	Highfield House Observatory.	E. J. Lowe	Ibid.
'rom γ Aquarii, nearly horizontally, inclining slightly downwards, and ending at the Milky Way.	....	Ibid..............	Id.	Ibid.
rom γ Lyræ, through 95 Herculis, coming from direction of the Swan.	No increase in size	Ibid..............	Id.	Ibid.
Ioving from E. to W. down at an angle of 45°, passing immediately under δ Ursæ Majoris, and crossing Canes Venatici.	Length of arc 15°..	Ibid..............	Id.	Ibid.
t was seen a little distance below and to the E. of Capella.	Cloudy...............	Royal Observatory, Greenwich.	W. C. Nash	Ibid.
'own at an angle of 60° from 3° below Arcturus.	....	Highfield House Observatory.	E. J. Lowe	Ibid.

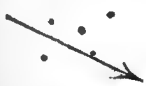
Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1861. Aug. 9	h m s 10 21 p.m.	=2nd mag.*	Reddish	Many sparks	Duration 0·2 sec.
9	10 21 p.m.	....	....	None	1 second
9	10 24 45 p.m.	=3rd mag.*	Yellowish	Streak left	Duration 0·2 sec.
9	10 29 p.m.	=3rd mag.*	Blue	Streak left	Instantaneous
9	10 29 5 p.m.	=3rd mag.*	Blue	Streak	Instantaneous
9	10 31 p.m.	Small	Blue	Small train	1 second
9	10 34 30 p.m.	=3rd mag.*	Yellow	Streak	Instantaneous
9	10 36 p.m.	=4th mag.*	Yellow	Streak	Instantaneous
9	10 37 p.m.	=3rd mag.*	Bluish	Streak	Instantaneous
9	10 38 p.m.	=2nd mag.*	....	Small train	2 seconds
9	10 41 40 p.m.	=3rd mag.*	Colourless	Streak 	Rapid; duratio 0·2 sec.
9	10 43 p.m.	=3rd mag.*	....	None	1 second
9	10 47 p.m.	Very bright	....	None	Momentary
9	10 47 50 p.m.	=3rd mag.*	Reddish	Streak, which remained after the meteor had itself vanished.	Duration 0·5 sec.
9	10 51 p.m.	=2nd mag.*	Reddish	Streak	Duration 0·2 sec.
9	10 52 30 p.m.	= ♃ in size, and increased in magnitude, and more especially in brightness.	Blue	Streak	Duration 0·3 sec disappeared maximum brigh ness suddenly.
9	10 52 31 p.m.	=6th mag.*	Colourless	Streak	Same speed as la and apparent connected wi it. Rapid.
9	10 55 p.m.	=1st mag.*	Deep blue	Leaving a thin streak	Duration 3 secs.
9	10 56 15 p.m.	=2nd mag.*	Colourless	Streak	Rapid; durati 0·2 sec.

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
tarting 10° N. of Sword-handle of Perseus.	Disappeared at maximum brightness. Arc 1°.	Highfield House Observatory.	E. J. Lowe	MS. communication.
rom Lacerta to α Delphini ...	Cloudy..............	Royal Observatory, Greenwh.	J. Howe	Ibid.
rom 5° below Polaris, and moving from direction of Sword-handle of Perseus.	Arc 3°	Highfield House	E. J. Lowe	Ibid.
cross γ Draconis from direction of Cassiopeia.	Arc 7°	Ibid...............	Id.	Ibid.
rom below Polaris, coming from direction of Cassiopeia.	Arc 5°	Ibid...............	Id.	Ibid.
rom α Aquilæ to α Ophiuchi.	....	Royal Observatory, Greenwich.	J. Howe	Ibid.
cross τ Cassiopeiæ, from direction of the Swan.	Arc 5°	Highfield House	E. J. Lowe	Ibid.
rom near ρ Ursæ Majoris down from direction of Perseus.	....	Ibid...............	Id.	Ibid.
rom slightly N. of ι Cassiopeiæ; rose upwards, inclining slightly N. (from direction of Perseus).	Arc 0° 30′	Ibid...............	Id.	Ibid.
rom α Cygni to α Coronæ Borealis.	....	Greenwich	J. Howe	Ibid.
rom below σ Aurigæ, and moved upward on a circular arc (discordant).	Arc 5°	Highfield House Observatory.	E. J. Lowe	Ibid.
ı a S.W. direction across Equuleus.	Cloudy..............	Royal Observatory, Greenwich.	W. C. Nash......	Ibid.
hot out from the clouds near Polaris.	....	Ibid...............	Id.	Ibid.
cross α Pegasi, and through ξ Pegasi (from direction of Perseus).	Arc 7°	Highfield House	E. J. Lowe	Ibid.
rom χ Ursæ Majoris (from direction of Perseus).	Arc 4°	Ibid...............	Id.	Ibid.
rom about H. 10 Camelopardi, crossing above σ Aurigæ (from direction of Perseus).	Arc 10°	Ibid...............	Id.	Ibid.
om H. 7 Camelopardi downwards at an angle of 45°.	....	Ibid...............	Id.	Ibid.
om near α Cygni, passing beyond and within a few degrees of α Pegasi.	Rather cloudy	Greenwich	J. MacDonald...	Ibid.
om H. 15 Ursæ Majoris down at an angle of 45° (from direction of Cassiopeia).	Arc 15°	Highfield House	E. J. Lowe	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1861. Aug. 9	h m s 10 57 40 p.m.	=2nd mag.*	Colourless	Streak	Rapid
9	10 59 p.m.	=3rd mag.*	Colourless	Streak	Very rapid; duration 0·1 sec.
9	11 4 p.m.	=1st mag.*	Reddish	Streak	Duration 0·5 sec.
9	11 4 1 p.m.	=2nd mag.*	Reddish	Streak	Duration 0·5 sec.
9	11 4 2 p.m.	=3rd mag.*	Colourless	Streak	Duration 0·2 sec.
9	11 16 p.m.	=3rd mag.*		None	1 second
9	11 33 p.m.	Fine		Left a train some degrees in length.	3 seconds
10	0 3 a.m.	Very small	White	None	Duration 0·5 sec.
10	9 15 p.m.	Small		None	1 second
10	9 18 p.m.	Small		None	1 second
10	9 20 p.m.	Magnificent meteor. The length of the head and body together was about equal to the distance between the pointers of the Great Bear.	The head appeared a mass of blue fire. The body a mixture of bright purple and crimson.	The tail was a long streak of red fire, from which sparks were emitted; which rapidly became extinct.	4 seconds
10	9 25 p.m.	=1st mag.*		Left a train 15° long	
10	9 30 p.m.	=1st mag.*		Left a train visible for 10 seconds.	
10	9 30 p.m.	Small	White	None	0·5 sec.
10	9 38 p.m.	=2nd mag.*			
10	9 43 p.m.	=3rd mag.*			
10	9 48 p.m.	=2nd mag.*	Green	Light streak	

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
?rom midway between α and γ Ursæ Majoris; fell down at an angle of 45° towards the N. horizon (from direction of Perseus).	Arc 10°	Highfield House	E. J. Lowe	MS. communication.
?rom just above α Ursæ Majoris down towards N. (from direction of Perseus).	Arc 5°	Ibid................	Id.	Ibid.
?ownwards in S.W., and crossing ι Coronæ Borealis.	Arc 18°	Ibid................	Id.	Ibid.
?rossing Arcturus, and falling downwards (from direction of Perseus).	Arc 15°	Ibid................	Id.	Ibid.
?own in N. below Polaris (from direction of Perseus).	Arc 5°. (From 11.10 p.m. cloudy night.)	Ibid................	Id.	Ibid.
?hot out from behind the clouds in a N.W. direction across Delphinus.	....	Royal Observatory, Greenwich.	W. C. Nash......	Ibid.
?rom Cassiopeia to δ Ursæ Majoris.	....	Ibid................	J. Howe	Ibid.
?rom γ Draconis to within about 10° of Arcturus.	Thin clouds.........	Greenwich	J. MacDonald...	Ibid.
?rom α Cygni to Cepheus	A very fine night...	Royal Observatory, Greenwich.	J. Howe	Ibid.
?rom Delphinus to α Pegasi ...	....	Ibid................	Id.	Ibid.
?om N.E. to S.W. at an elevation 50° above the horizon. The apparent distance travelled by the meteor was fully one-third of the chord of the celestial arc, occupying while visible the central part thereof.	A clearly defined streak of yellowish-red light was left behind, visible for about 4 minutes. Several meteors were seen on this evening.	Midway between Bilbao and the mouth of the river about 5 miles from the sea.	H. Vignoles ...	Ibid.
?ll from α Lyræ towards the E. ⟶ S	....	Cranford	W. De la Rue ...	Ibid.
?early in zenith; trail remained visible for 10 seconds to the W. of α Lyræ.	....	Ibid................	Id.	Ibid.
?om the neighbourhood of Ursa Minor, in the direction of Arcturus for about 15°.	Clear	Greenwich	J. MacDonald...	Ibid.
?ntre of track E.S.E. from 3° below α Pegasi to α Aquarii. ⟶ S	....	Cranford	W. De la Rue ...	Ibid.
?ntre of track E.S.E., in a direction parallel to N. 3°. ⟶ S	....	Ibid................	Id.	Ibid.
?om Cassiopeia towards α Pegasi.	....	Greenwich	J. MacDonald...	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1861. Aug. 10	h m 9 49 p.m.	=2nd mag.*	....	....	....
10	9 53 p.m.	....	....	....	....
10	9 56 p.m.	=3rd mag.*	Blue	None	2 seconds
10	9 31 p.m.	Fine	....	Leaving a train some degrees in length.	3 seconds
10	9 38 p.m.	=1st mag.*	....	Leaving a train 20° in length.	2 seconds
10	9 56 p.m.	....	....	....	....
10	9 57 p.m.	=2nd mag.*	....	None	1 second
10	9 59 p.m.	....	....	....	....
10	10 1 p.m.	Small	....	None	Momentary
10	10 1 p.m.	....	....	....	....
10	10 2 p.m.	....	....	....	....
10	10 6½ p.m.	=2nd mag.*	....	None	1 second
10	10 7 p.m.	=2nd mag.*	....	....	....
10	10 9¼ p.m.	=2nd mag.*	....	None	2 seconds
10	10 10¼ p.m.	=3rd mag.*	....	None	1 second
10	10 14 p.m.	=2nd mag.*	....	....	....
10	10 15 p.m.	....	....	....	....

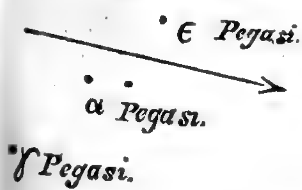
Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
Centre of track S.S.W.; moved from β Aquilæ for 20°. 	....	Cranford	W. De la Rue ...	MS. communication.
Centre of track E., about 10° above horizon. 	....	Ibid...............	Id.	Ibid.
rom a few degrees N. of the horizon, continuing very nearly parallel to it for about 15°.	....	Greenwich	J. MacDonald ...	Ibid.
fine meteor was seen to pass from α Draconis to Arcturus.	....	Ibid...............	J. Howe	Ibid.
rom α Aquilæ to Cassiopeia...	....	Ibid...............	Id.	Ibid.
entre of track S.W. .... 	....	Cranford	W. De la Rue ...	Ibid.
assed rapidly from Polaris to α Ursæ Majoris.	....	Greenwich	W. C. Nash	Ibid.
entre of track S.E., near α Aquilæ. 	....	Cranford	W. De la Rue ...	Ibid.
rom λ Draconis towards the N. horizon.	....	Greenwich	W. C. Nash	Ibid.
entre of track S.S.E., 10° above horizon.	....	Cranford	W. De la Rue ...	Ibid.
entre of track S.S.E., pointing to α Aquilæ.	....	Ibid...............	Id.	Ibid.
owards the horizon, across Camelopardus.	....	Greenwich	W. C. Nash	Ibid.
entre of track E.N.E., elevation 15°.	....	Cranford	W. De la Rue ...	Ibid.
om a point a few degrees above Arcturus in a S.W. direction.	....	Greenwich	W. C. Nash	Ibid.
om β Ophiuchi to Scorpius...	....	Ibid...............	Id.	Ibid.
entre of path S. through Cygnus. 	....	Cranford	W. De la Rue ...	Ibid.
ntre of path S.E., below Cygnus. 	....	Ibid...............	Id.	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1861.	h m				
Aug. 10	10 16 p.m.	=1st mag.*	.....	Leaving a train about 15° in length.	2 seconds
10	10 18 p.m.	= 1st mag.*, as brilliant as Venus.	.....	.....	.....
10	10 19 p.m.	=2nd mag.*	.....	Fine train	1 second
10	10 20 p.m.	Small	.....	None	1 second
10	10 21 p.m.	=3rd mag.*	.....	A train about 10° in length.	1 to 2 secs.
10	10 23 p.m.	Small	.....	Faint train	1 second
10	10 23½ p.m.	Small	.....	None	1 second
10	10 24 p.m.	.....	.....	.....	.....
10	10 24 p.m.	Small	.....	None	1 second
10	10 25 p.m.	=1st mag.*	.....	Leaving a train some degrees in length.	2 seconds
10	10 25 p.m.	Two meteors, both brilliant ; = 1st mag.*.	.....	.....	.....
10	10 26 p.m.	=2nd mag.*	.....	None	1 second
10	10 26 p.m.	.....	.....	.....	.....
10	10 27 p.m.	=1st mag.*	.....	Left a train	.....
10	10 27 p.m.	=2nd mag.*	Bluish	A train about 5° in length	2 seconds
10	10 27 p.m.	Small	.....	None	1 second

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
From δ Ursæ Majoris to within a few degrees of Arcturus.	....	Greenwich	J. Howe	MS. communication.
Centre of path S.S.E.	....	Cranford	W. De la Rue ...	Ibid.

From Equuleus to α Capricorni	....	Greenwich	W. C. Nash	Ibid.
From Cassiopeia to α Persei ...	....	Ibid...............	J. Howe	Ibid.
From Lacerta to Delphinus ...	....	Ibid...............	W. C. Nash	Ibid.
From γ Ursæ Majoris to ι Virginis.	....	Ibid...............	J. Howe	Ibid.
From α Herculis towards the S.W. horizon.	....	Ibid...............	W. C. Nash	Ibid.
Centre of path S.W., 3° below α Lyræ.	....	Cranford	W. De la Rue ...	Ibid.
From α Cygni to α Herculis ...	....	Greenwich	W. C. Nash	Ibid.
From Polaris to Corona Borealis	....	Ibid...............	J. Howe	Ibid.
Centre of path E.	....	Cranford	W. De la Rue ...	Ibid.

near Cygnus.				
Appeared a few degrees below α Pegasi, and pursued a course about 15° in length parallel to the S. horizon.	....	Greenwich	W. C. Nash	Ibid.
Centre of path E.S.E., near horizon.	....	Cranford	W. De la Rue ...	Ibid.
Centre of path E.S.E.	....	Ibid...............	Id.	Ibid.



Appeared at a point a few degrees above α Andromedæ to between α and β Pegasi.	....	Royal Observatory, Greenwich.	W. C. Nash	Ibid.
Passed from α Coronæ Borealis to α Serpentis.	....	Ibid...............	J. Howe	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1861. Aug. 10	h m 10 28 p.m.	Small	....	None	1 second
10	10 28 p.m.	....	....	....	....
10	10 29 p.m.	= 1st mag.*, brilliant as Venus.	....	Left a long train 15° long	....
10	10 31 p.m.	= 2nd mag.*	....	Small train	1 sec.
10	10 32 p.m.	= 2nd mag.*	....	....	1 sec.
10	10 32 p.m.	= 1st mag.*	Bright	....	....
10	10 32½ p.m.	= 2nd mag.*	....	....	1 sec.
10	10 35½ p.m.	= 2nd mag.*	Blue	....	1 to 2 seconds
10	10 37½ p.m.	= 2nd mag.*	....	None	Momentary
10	10 38 p.m.	Fine	....	Train of some degrees in length.	2 seconds
10	10 39 p.m.	= 1st mag.*	....	....	....
10	10 39 p.m.	= 2nd mag.*	....	Leaving a train	2 seconds
10	10 42 p.m.	Small	....	None	1 second
10	10 42 p.m.	....	....	....	....
10	10 43 p.m.	Very bright	....	Small train	1 second
10	10 45 p.m.	Small	....	None	1 second
10	10 47 p.m.	Small but very bright	....	None	1 second
10	10 49 p.m.	Small	....	None	1 second
10	10 50½ p.m.	= 3rd mag.*	....	None	1 second
10	10 51 p.m.	Small	....	None	1 second
10	10 51½ p.m.	Small	....	None	Almost momentary
10	10 52 p.m.	Small	....	None	1 second
10	10 56½ p.m.	= 3rd mag.*	....	None	1 second
10	10 58 p.m.	Very fine	....	Leaving a beautiful train about 30° in length.	2 seconds
10	11 14 p.m.	= 1st mag.*	Blue	A train about 20° in length	2 to 3 seconds
10	11 17 p.m.	Small	....	None	1 second
10	11 59 p.m.	= 2nd mag.*	....	Small train	2 seconds
11	1 50 a.m.	= 3rd mag.*	Colourless	Streak	Instantaneous
11	1 51 a.m.	Increased to 1st mag.*, and disappeared at maximum brightness.	Red, & 3 times as bright as 1st mag.*.	Train	Very rapid

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
From α Herculis to α Lyræ ...	....	Royal Observatory, Greenwich.	J. Howe	MS. communication.
Centre of track E.N.E., 15° above horizon.	....	Cranford	W. De la Rue ...	Ibid.
Appeared about 30° above horizon, disappeared about 15° above horizon.	....	Ibid................	Id.	Ibid.
From Cassiopeia to α Persei ...	....	Royal Observatory, Greenwich.	J. Howe	Ibid.
From β Draconis to δ Ursæ Majoris.	....	Ibid................	Id.	Ibid.
Centre of track E.N.E., about 30° above horizon.	....	Cranford	W. De la Rue ...	Ibid.
Passed from γ Ursæ Majoris to the N.W. horizon.	....	Royal Observatory, Greenwich.	W. C. Nash	Ibid.
Passed from α Andromedæ to α Pegasi.	....	Ibid................	Id.	Ibid.
From λ Pegasi to β Pegasi......	....	Ibid................	Id.	Ibid.
From β Ursæ Majoris to Leo Minor.	....	Ibid................	J. Howe	Ibid.
Centre of path E.S.E., 4° above horizon.	....	Cranford	W. De la Rue ...	Ibid.
From a point situated between β Cygni and Sagitta to μ Herculis.	....	Royal Observatory, Greenwich.	W. C. Nash	Ibid.
From Corona Borealis to α Lyræ.	....	Ibid................	J. Howe	Ibid.
Centre of path S.E., 9° above horizon.	Cloudy..............	Cranford	W. De la Rue ...	Ibid.
From ι Delphini to a little above γ Aquilæ.	....	Royal Observatory, Greenwich.	W. C. Nash	Ibid.
From δ Serpentis to α Libræ...	....	Ibid................	J. Howe	Ibid.
Fell perpendicularly from β Arietis to the horizon.	....	Ibid................	W. C. Nash	Ibid.
From α Herculis to α Scorpii.	....	Ibid................	J. Howe	Ibid.
Passed from α Cygni to α Lyræ.	....	Ibid................	W. C. Nash	Ibid.
From α Cygni to β Delphini ...	....	Ibid................	J. Howe	Ibid.
Passed rapidly a few degrees above γ Pegasi.	....	Ibid................	W. C. Nash	Ibid.
From ι Cygni to Equuleus	....	Ibid................	Id.	Ibid.
Passed rapidly from η Andromedæ to γ Pegasi.	....	Ibid................	Id.	Ibid.
From α Pegasi past Delphinus to α Aquilæ.	....	Ibid................	J. Howe	Ibid.
From α Lyræ to δ Serpentis ...	....	Ibid................	W. C. Nash	Ibid.
From β Ursæ Majoris towards the N. horizon.	....	Ibid................	Id.	Ibid.
Passed in a S.E. direction across γ Pegasi.	....	Ibid................	Id.	Ibid.
Across centre of Pegasus, coming from direction of Perseus.	Arc 20°	Highfield House Observatory.	E. J. Lowe	Ibid.
From direction of Perseus, and passing 10° N. of Aldebaran.	Arc 9°	Ibid................	Id.	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1861.	h m s				
Aug. 11	1 51 20 a.m.	=1st mag.*	Red, very bright.	Train	Rapid
11	1 53 a.m.	=3rd mag.*	Bluish	Streaks	0·2 sec.
11	1 58 a.m.	=2nd mag.*	Blue	Streak	0·2 sec.
11	1 59 a.m.	=2nd mag.*	Blue	Streak	0·2 sec.
11	1 59 a.m.	=2nd mag.*	Blue	Streak	0·2 sec.
11	1 59 40 a.m.	= 2♃	Very bright red.	A long tail which lingered	Rapid
11	1 59 45 a.m.				
11	2 2 a.m.	=3rd mag *	Blue	Streak	0·1 sec.
11	2 5 a.m.	Small	Indistinct	Streak	Rapid
11	2 5 5 a.m.	Small		Streak	Rapid
11	2 6 a.m.	=2nd mag.*		Streak	Rapid
11	2 6 30 a.m.	=2nd mag.*	Blue	Streaks	Rapid
11	2 9 30 a.m.	=3rd mag.*	Blue	Streak	Rapid
11	2 11 a.m.	=2nd mag.*	Red	Streak	0·2 sec.
11	2 12 a.m.	=1st mag.*	Red	Streak	0·2 sec.
11	2 14 a.m.	=2nd mag.*	Blue	Streak	Rapid
11	2 14 30 a.m.	=3rd mag.*	Red	Streak	Rapid
11	2 15 a.m.	=2nd mag.*	Colourless	Streak	Rapid
11	2 15 30 a.m.	=2nd mag.*	Colourless	Streak	Rapid
11	2 17 a.m.	=2nd mag.*	Blue	Streak	Rapid
11	2 17 15 a.m.	Small			
11	2 18 a.m.	Small			Rapid
11	2 20 a.m.	Small	Colourless	Streak	Rapid
11	2 20 15 a.m.	Small	Colourless	Streak	Rapid
11	2 22 30 a.m.	= 3rd mag.*	Colourless	Streak	Rapid

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
rom direction of Perseus, amongst cloud in N.E.; altitude 40°.	....	Highfield House Observatory.	E. J. Lowe	MS. communication.
rom 1° S. of Sword-handle of Perseus.	Arc 1°	Ibid...............	Id.	Ibid.
rom direction of Perseus, starting exactly on Aldebaran.	Arc 5°; faded at max. brightness.	Ibid...............	Id.	Ibid.
rom direction of Perseus, down from Capella.	....	Ibid...............	Id.	Ibid.
rom direction of Perseus, near E. horizon.	....	Ibid...............	Id.	Ibid.
rom direction of Perseus, starting 15° from the Sword-handle of Perseus, and passing across δ Ursæ Majoris.	Arc 30°	Ibid...............	Id.	Ibid.
ne in N.W., altitude 45° amongst cloud.	....	Ibid...............	Id.	Ibid.
rom direction of Perseus, down, passing midway between Pleiades and Capella.	....	Ibid...............	Id.	Ibid.
N., from direction of Perseus.	....	Ibid...............	Id.	Ibid.
Ursa Major....................	....	Ibid...............	Id.	Ibid.
N., moving towards Ursa Major.	Arc 10°, from direction of Perseus.	Ibid...............	Id.	Ibid.
N.E. (from direction of Perseus).	Arc 10°	Ibid...............	Id.	Ibid.
)' E. of Aldebaran, from direction of Perseus.	Arc 5°	Ibid...............	Id.	Ibid.
pwards across Cassiopeia, from direction of Perseus.	Arc 5°	Ibid...............	Id.	Ibid.
N.E., from 15° above the horizon, falling perpendicularly down.	....	Ibid............	Id.	Ibid.
om direction of Perseus, moving across the Ram.	....	Ibid...............	Id.	Ibid.
om direction of Perseus, crossing Pleiades.	....	Ibid...............	Id.	Ibid.
om direction of Perseus, starting 3° S. of Pleiades, falling down at an angle of 50°.	....	Ibid...............	Id.	Ibid.
om direction of Perseus, crossing α Pegasi.	....	Ibid...............	Id.	Ibid.
' below Pleiades, from direction of Pleiades.	....	Ibid...............	Id.	Ibid.
N.E. amongst clouds.........	....	Ibid...............	Id.	Ibid.
om direction of Perseus, perpendicularly down to Castor.	....	Ibid...............	Id.	Ibid.
own towards Aries, from direction of Perseus.	....	Ibid...............	Id.	Ibid.
oove Aries......................	....	Ibid...............	Id.	Ibid.
om γ Pegasi down	....	Ibid...............	Id.	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1861. Aug. 11	h m s 2 22 30 a.m.	=3rd mag.*	Colourless	Streak	Rapid
11	2 22 40 a.m.	=3rd mag.*	Colourless	Streak	Rapid
11	9 20 p.m.	=2nd mag.*	Blue	Streak	Rapid
11	9 24 p.m.	=2nd mag.*	......	Streak	Rapid
11	10 47 p.m.	Small	......	......	......
11	10 47 30 p.m.	Small	......	......	......
11	10 48 p.m.	Small	......	Streak	Rapid
11	10 50 p.m.	=3rd mag.*	Colourless	Streak	Rapid
12	12 59 a.m.	=3rd mag.*	Colourless	Streak	0·2 sec.
12	12 59 20 a.m.	=3rd mag.*	Colourless	Streak	0·2 sec.
12	1 0 a.m.	=3rd mag.*	Colourless	Streak	0·1 sec.
12	1 0 10 a.m.	=3rd mag.*	Colourless	Streak	Rapid
12	1 2 a.m.	=3rd mag.*	Colourless	Streak	Rapid
12	1 6 30 a.m.	=2nd mag.*	Colourless	Streak	......
12	1 10 a.m.	=6th mag.*	Colourless	Streaks	......
12	1 14 a.m.	=6th mag.*	Colourless	Streak	Rapid
12	1 18 a.m.	=3rd mag.*	Colourless	Streak	Rapid
12	1 20 a.m.	=3rd mag.*	Colourless	Streak	Rapid
12	1 20 30 a.m.	=3rd mag.*	Colourless	Streak	Rapid
12	1 22 a.m.	=3rd mag.*	Colourless	Streak	Rapid
12	1 24 a.m.	=3rd mag.*	Colourless	Streak	Rapid
12	1 27 a.m.	=2nd mag.*	Colourless	Streak	Rapid
12	1 29 30 a.m.	Small	Colourless	Streak	Rapid
12	10 0 p.m.	Small	......	None	1 second
12	10 2 p.m.	Small	......	None	1 second
12	10 41½ p.m.	Very bright, =2nd mag.*	Blue	Leaving a train 10° in length.	1 to 2 seconds.
13	9 25 p.m.	=1st mag.*	Colourless	Train	Slow
13	9 26 p.m.	=1st mag.*	Bluish	Train	Slow
13	10 1 p.m.	=3rd mag.*	Blue	Train	2 seconds

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
om direction of Perseus; at 2.24 a.m. became cloudy.	....	Highfield House Observatory.	E. J. Lowe	MS. communication.
Cassiopeia	....	Ibid.............	Id.	Ibid.
om amongst clouds, in N.E., perpendicularly down.	....	Ibid.............	Id.	Ibid.
ross Arcturus (from direction of Perseus).	....	Ibid.............	Id.	Ibid.
ross Arcturus	....	Ibid.............	Id.	Ibid.
S.W., half-way to zenith ...	....	Ibid.............	Id.	Ibid.
om γ Capricorni (direction of Perseus).	....	Ibid.............	Id.	Ibid.
om θ Ursæ Majoris (from direction of Perseus).	....	Ibid.............	Id.	Ibid.
om direction of Perseus, downwards at an angle of 45° to near S.S.E. horizon.	Arc 20°	Ibid.............	Id.	Ibid.
om direction of Perseus, crossing ι Delphini.	....	Ibid.............	Id.	Ibid.
om direction of Swan, crossing β Arietis.	....	Ibid.............	Id.	Ibid.
ross ν Pegasi, from direction of Perseus.	....	Ibid.............	Id.	Ibid.
om about 14 Arietis, from direction of Perseus.	Arc 7°	Ibid.............	Id.	Ibid.
om direction of Perseus, crossing half below ω Piscium and γ Pegasi.	Arc 15°	Ibid.............	Id.	Ibid.
veral small meteors	....	Ibid.............	Id.	Ibid.
ar Sword-handle of Perseus, on S.E. side.	Arc 12′	Ibid.............	Id.	Ibid.
ossing ζ Pegasi, from direction of Perseus.	Arc 10°	Ibid.............	Id.	Ibid.
N.E., altitude 45°, down at an angle of 80°, from direction of Perseus.	Arc 10°	Ibid.............	Id.	Ibid.
N.E., altitude 55°, down at an angle of 45°, from direction of Perseus.	Arc 3°	Ibid.............	Id.	Ibid.
ossing η Piscium, from direction of Perseus.	....	Ibid.............	Id.	Ibid.
t under Polaris	....	Ibid.............	Id.	Ibid.
wards from Algol, perpendic. Discordant.	Arc 3°	Ibid.............	Id.	Ibid.
wn from below γ Andromedæ (from Cygnus).	Arc 5°	Ibid.............	Id.	Ibid.
sed from Cassiopeia to α Pegasi.	....	Royal Observatory, Greenwich.	J. Howe	Ibid.
m Polaris to Cassiopeia ...	....	Ibid.............	Id.	Ibid.
m λ Lyræ to α Herculis ...	....	Ibid.............	W. C. Nash and J. Howe.	Ibid.
wn across Aquarius (from irection of Perseus).	....	Highfield House Observatory.	E. J. Lowe	Ibid.
m near α Pegasi. Discordant	....	Ibid.............	Id.	Ibid.
sed from β to γ Pegasi......	....	Royal Observatory, Greenwich.	W. C. Nash	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1861. Aug. 14	h m s 12 39 30 a.m.	=3rd mag.*	Colourless ...	Small train	0·5 sec............
14	12 39 45 a.m.	=3rd mag.*	Colourless ...	Small train	Slow, duration 0· sec.
14	12 44 a.m.	=4th mag.*	Colourless ...	Small train	Instantaneous .....
14	12 45 a.m.	=3rd mag.*	Colourless ...	Streak	Rapid, duration 0· sec.
14	12 47 a.m.	=3rd mag.*	Colourless ...	Streak	Rapid, duration 0· sec.
14	12 50 16 a.m.	=3rd mag.*	Reddish	Streak	Rapid ....
14	12 51 5 a.m.	=2nd mag.*	Blue	Streak	0·3 sec............
14	1 4 a.m.	=3rd mag.*	Colourless ...	Train	Instantaneous .....
14	10 5 p.m.	=1st mag.*	White	A long and bright train ...	3 seconds..........
14	10 15 p.m.	=2nd mag.*	....	Small train	2 seconds..........
14	10 32 p.m.	Small	....	None	1 second ....
14	10 34 p.m.	Small	....	None	1 second ....
14	11 14 p.m.	=3rd mag.*	....	None	1 second ....
14	11 27 p.m.	=3rd mag.*	White	Small train	1 second ....
15	9 59 p.m.	=2nd mag.*	White	Short train	1 second ....
15	10 8 p.m.	=2nd mag.*	....	Small train	1 to 2 seconds....
21	8 53 p.m.	Large	White	....	3 or 4 seconds....
26	11 5 p.m.	= 1st mag.*	Blue	Leaving a thin streak of light.	1 to 2 seconds....
29	10 7 p.m.	Small	....	None	1 second ....

APPENDIX.

No. 1.—A large meteor, October 25th, 1859, was seen at Holyhead, Anglesea; and at Ballinaman, 13 miles west of Athlone, in Ireland.

1. As seen by Mr. Harris, C.E., at Holyhead.—At about 7.15 P.M. a bright ball of fire appeared directly overhead, illuminating the dense masses of vapour which filled the sky at the time, and rendering objects around as visible as if by day. The appearance lasted two or three seconds; it was blowing nearly a gale at the time, and immediately after the rain came down like a deluge.

2. As seen by Thomas C. Carter, about 13 miles west of Athlone.—The

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
ɔwn across α Arietis, from direction of Perseus.	Arc 5°	Highfield House Observatory.	E. J. Lowe	MS. communication.
om Sword-handle of Perseus. From direction of Perseus.	Arc 3°	Ibid...............	Id.	Ibid.
ross β Andromedæ, from direction of Perseus.	Arc 7°..............	Ibid...............	Id.	Ibid.
ɔwn from just above α Andromedæ.	Direction of Cassiopeia.	Ibid...............	Id.	Ibid.
ɔwn from between β and γ Andromedæ.	Direction of Cassiopeia.	Ibid...............	Id.	Ibid.
) from 10′ S. of γ Andromedæ.	Arc 3°. Discordant	Ibid...............	Id.	Ibid.
rpendicular down, inclining E. from Swan to 12° N. of Perseus.	Arc 15°	Ibid...............	Id.	Ibid.
ɔm η Pegasi towards Cassiopeia.	Discordant	Ibid...............	Id.	Ibid.
ssed from 5° E. of α Lyræ to α Coronæ Borealis.	....	Blackheath	J. Glaisher	Ibid.
Cygni to Cassiopeia...........	....	New Cross	J. Howe	Ibid.
ɔm α Draconis to δ Cygni ...	....	Ibid...............	Id.	Ibid.
ɔm β Pegasi direct, downward course to horizon.	....	Ibid...............	Id.	Ibid.
ɔm β Trianguli to β Persei...	....	Greenwich	W. C. Nash	Ibid.
ɔm β Persei to α Arietis......	....	Highfield House Observatory.	E. J. Lowe	Ibid.
ssed from β Cygni to ι Aquilæ.	....	Greenwich	W. C. Nash	Ibid.
ssed from α Cygni to Cassiopeia.	....	Ibid...............	J. Howe	Ibid.
descended vertically from 10° S. of Arcturus for a distance of about 8°, disappearing behind a cloud.	....	Royal Hospital, Greenwich.	W. T. Lynn	Ibid.
l from the neighbourhood of Polaris towards the northern horizon for about 10°.	Very fine, stars very bright.	Greenwich, Trafalgar Road.	J. MacDonald ...	Ibid.
ll from the zenith, passing through the tail of Ursæ Majoris, disappearing about 10° below.	Fine	Greenwich, Nelson Street.	Id.	Ibid.

sky was clear, when about 7.30 P.M. (Irish time?) a meteor, at first about the size of a star of the first magnitude, swiftly approached from the direction of the Pleiades; it advanced rapidly, increasing in size, for about four or five seconds, giving out an intensely white light; at the end of that time it changed colour to a bright ruby-red, and then it seemed to change its course as well as to lose velocity; almost immediately after that it burst into fifteen or sixteen bright-green particles that remained visible some two seconds more, and then altogether disappeared. The whole phenomenon lasted perhaps eight seconds; its direction was about N.W. or N.N.W.*

* There can be little doubt that these two observations related to one and the same meteor.

No. 2.—The following accounts of the remarkable meteor of June 11th, 1845, of which some descriptions have already been published in preceding Reports, have been forwarded to us, as first seen by the Rev. F. Hawlett, F.R.A.S., near Adalia, Asia Minor:—

1. Towards the close of the 18th we started, after one of the sultriest days I almost ever experienced; at 11 A.M. the thermometer was 98° in the coolest part of Mr. Purdie's house, whilst not a breath of wind was astir. I know not whether the stagnant heat may have contributed to the occurrence of a very splendid meteor which we witnessed that evening. We had entered the mountainous district north-west of Adalia, the sun had recently set in a perfectly cloudless sky, and the twilight was coming on, when there suddenly burst out in the north a meteor that resembled in appearance a bright but permanent flash of lightning, whose upper extremity lay a little to the east of the pole-star. The length of the flash, as near as I could judge, was about 50°—certainly more than half the space between the zenith and the horizon (sloping downwards towards the west of north); and that which I presumed was the vapour resulting from the explosion presented for several minutes the same shape as the original flash, and being strongly illumined (as I took it) by the upslanting rays of the vanished sun, appeared about the brightness of the rising moon, which was then about at the full. Absorbed as we all were by the magnificence of the spectacle, which elicited from the Turks repeated cries of "Allah, Allah," I forgot to note by my watch the time which might elapse until an explosion should be audible, and was only reminded of the omission upon hearing a dull heavy report like that of a distant piece of ordnance boom on my ear, after an interval we then judged of some 7 or 8 minutes. According to this estimate, the sound, if it came to us from the meteor, and which (it was so peculiar) I think was the case, must have travelled to us from a distance of 90 miles (sound travelling 1140 feet per second), and owing to the altitude of the meteor must have had its origin in the highest and rarest regions of our atmosphere.

This brilliant visitant gradually appeared to grow larger and more diffuse, as to breadth more particularly, and at last to break up into detached portions, which were beautifully decked in luminous colours of red, orange, and silvery green. Finally the coloured portions, having taken meanwhile a slightly westerly course, by degrees faded away, having continued visible at least 20 minutes to half an hour. We were informed that the meteor was seen at Philadelphia (160 miles west).

2. From 'Malta Mail.'

The brig 'Victoria' saw this extraordinary appearance when in latitude 36° 40′ 56″ north, and longitude 13° 44′ 36″ east, being becalmed and without any appearance of bad weather; her topgallant and royal masts suddenly went over the side, as if carried away by a sudden squall; and two hours after it blew very hard from south and east, but suddenly again fell calm, with an overpowering stench of sulphur and an unbearable heat. At this moment three luminous bodies were seen to issue from the sea at the distance of about half a mile from the vessel, which remained visible for about 10 minutes; soon after it came on to blow hard from the south-east, and the vessel ran into a current of air the reverse of that just experienced (900 miles west of Adalia).

3. Letter from Amab, on Mount Lebanon.

On the same day, about half an hour after sunset (very nearly the same time), the heavens presented an extraordinary and beautiful appearance. A fiery meteor, composed of two luminous bodies, each appearing at least five times larger than the moon, with streamers and appendages to each, joining the two, and looking like large flags blown out by a gentle breeze, appeared in the west, remained visible for an hour, and taking an easterly course gradually disappeared. The appendages appeared to shine from the reflected light of the main bodies, which it was painful to look at for any length of time. The moon had risen half an hour before, and there was scarcely any wind (350 miles south-east of Adalia).

Accounts from Erzeroum, in Asia Minor, describe a sudden fall of the thermometer on June 21st (three days after), which usually ranges in summer between 20° and 22° Reaumur, to 5°, and a further fall of two more degrees during a heavy snow-storm which lasted three days, after which the thermometer suddenly rose to 21°. The greatest consternation prevailed among the inhabitants, who thought the world was coming to an end.

At Malta the heat was excessively oppressive, the thermometer ranging from 87° indoors in shade to 140° exposed to the hot air. At St. Antonio, the coolest spot in the island, the governor was compelled to rig up Indian punkahs and order an extra supply of ice*.

No. 3.—The following additional notice of the meteor of July 16th has recently appeared in the 'London Review' of August 10th, 1861, written by Mr. Alexander S. Herschel:—

"Excellent observations at Tunbridge Wells, and at Darlington, in Yorkshire, afford the following conclusions upon the orbit of the first meteor of Tuesday evening, the 16th of July. If this were not an electrical phenomenon of extraordinary magnificence, it came from space as a body of one-third of a mile in diameter, drawn towards our sun from some initial path, in which it must have had a native velocity of at least twenty-three miles a second (exceeding by four miles that of our earth in her orbit). The meteor first became visible 320 miles above Namur (in the south of Flanders), and inclined downwards at 20° to about 100 miles above the North Sea, 250 miles due east of Perth, where it suddenly disappeared, soon after separating into two parts. The whole course of 500 miles was performed in 10 to 12 seconds of time; and if we neglect the action of the earth, which can only deflect a satellite 3° in a minute, the path was from over the head of Sagittarius, and presents a direct hyperbolic orbit of eccentricity of 1·11°, and obliquity 45°, leading from the descending node (where it encountered the earth) to an apse at 156° in advance along its course, and within 16,000,000 miles of the sun."

Note.—The time of this meteor is not given by Mr. Herschel in this notice, but he speaks of it as the first meteor seen that evening; it is very possible that this was the one seen also at Greenwich, the Isle of Wight, and Kensington, about 11 P.M., though it does not appear to be quite clear. It may be observed that large meteors seem to have been not unfrequently observed about the 17th of July. An observed altitude of 320 miles for a meteor is most unusual. Though it is true, as observed by Mr. Herschel, and proved by elaborate calculations by Walker (see 'American Philosophical Transactions' for 1841), that the influence of the earth's attraction is very inconsiderable on passing meteors, yet in calculations on the real orbits of meteors, taken generally from observations founded on positions more or less within the limits of the atmosphere, it must not be forgotten that the elasticity of the atmosphere itself must have a tendency to make the meteor deviate more or less from its true path, materially qualifying the elements of its ellipticity, and rendering somewhat uncertain whether it is hyperbolic or not.

* Sir W. S. Harris considers it probable this was an electrical phenomenon.

No. 4.—1. One of the most interesting falls of meteorites, and for a long time the only one of metallic iron which had been witnessed, took place at Hraschina, near Agram, on May 26th, 1751. At a meeting of the Imperial Academy of Vienna, April 14th, 1859, M. Haidinger produced the Latin document referring to it (which had never been published), and the original German translation; also a *second* document, lately discovered in the Imperial Cabinet of Minerals at Vienna, accompanied by two plates representing the phenomena as observed at Szigetvár (or Gross-Sziget), 75 miles east of Hraschina. At a meeting held on February 3rd, 1860, he presented a third document, discovered in the archiepiscopal library at Agram, describing the same phenomena as seen at Biscupecz, near Warasdin, 17½ miles north, a little east of Hraschina.

Prof. Haidinger also drew attention to the meteor seen on May 26, 1751, between 6 and 7 P.M., west of Gross-Sziget. It was first observed as a flash of light, without noise; immediately afterwards it resembled a tortuous chain, extending directly west, terminating in the middle height of the air as a fireball, leaving a long tail. On arriving in the lower strata it resembled an enormous sparkling fireball, with a chain-like tail in the higher regions, the last traces of which faded away at about 10 P.M. At Biscupecz it was observed as a small cloud from which some noise emanated, and which afterwards disappeared*.

Two pieces of iron fell to the east of Hraschina, one of 71 lbs. penetrating 4 feet 6 inches into the ground, at present preserved in the Imperial Cabinet of Vienna; the other of 16 lbs., which had been distributed partly at the place of its fall, and afterwards at Presburg, every vestige of which is lost. From the computations of various observations it appears to have passed from Neustadt to Hraschina, or from north to south from 48° 35′ to 40° 6′ 2″; and from west to east from 28° 18′ to 34°, east of Ferro.

No observations were taken of its velocity; but its height before its fall at Hraschina, viewed from Szigetvár, was from 30° to 35°—equal to about 43 to 52½ miles. Prof. Haidinger remarked upon the vast difference between the apparent size of the meteor and its solid contents. A body 15 inches in diameter at 75 miles distance is invisible; yet the meteor is pictured as if of the size of the sun. The appearance of the chain indicates the time when the solid portions became visible; they are, however, only the paths of the luminous bodies; and that they do not form straight lines is very natural, if we take into consideration the flat shape of the meteorite, which must have been tossed from side to side by the resistance of the air. If the rapid compression of the air is sufficient to annul the cosmical velocity, it certainly can produce the elimination of light—the fiery phenomena. These two points established, as a natural consequence two phenomena result, which belong to the character of fiery meteors. The solid nucleus of a meteor is not a globe; it passes undoubtedly through the resisting medium with its centre of gravity foremost, producing, on account of the unequal distribution, a rotation of its mass, which increases in rapidity, whilst the velocity of its motion diminishes in a direct ratio.

The report of the Hraschina meteor was heard as far as Warasdin, which, taking Hraschina as a centre, gives an area of nearly 1000 square miles over which the sound was audible.

The Hraschina iron was the first in which the highly crystalline structure of meteoric iron was observed, and Haidinger gives an account of the circumstances under which the discovery was made. Alvis von Widmannstätten, a highly educated and thorough iron-master, had a plate of the mass cut

* See American Journal of Science, 2nd series, vol. xxxii. No. 94, July 1861.

off $1\frac{3}{4}$ by 1 inch in size and $\frac{3}{16}$ oz. in weight; this was carefully polished for the purpose of examination when exposed to heat. But what a surprise! After the colour of the principal mass had passed through the various shades of straw-yellow, brownish-yellow, violet, and blue, there remained groups of triangles of straw-colour parallel lines, the blue and violet intervals $\frac{1}{4}$ to $\frac{1}{2}$ line wide, the straw-yellow lines $\frac{1}{6}$ to $\frac{1}{4}$—a splendid phenomenon. This was the first observation, and the figures were called "Widmanstätten's figures," in honour of the discoverer. The method of etching by acids was introduced after this discovery.

2. *Leitform.*—In a paper on a typical form of meteorites, presented at the meeting of the Imperial Academy of Vienna, on April 19th, 1860, by Prof. Haidinger, he suggests some new and interesting ideas. The paper is accompanied by two plates of the appearances of meteoric stones from Stannern and Gross-Dwina, which are complete in themselves, and may be considered as individuals of their kind, which at the same time show distinctly one of the periods through which they have passed.

In viewing meteorites there must be a starting-point from some fundamental considerations proved by the phenomena themselves, in order to arrive at an understanding of their forms and conditions. These are, 1st, the stone leaving the extra-terrestrial space as a solid; 2nd, its velocity being greater on entering the earth's atmosphere; 3rd, it is retarded by the resistance of the air; 4th, the "fireball" (or luminous envelope of the meteor) formed by the compression of the air and the rotation of the stone resulting therefrom; 5th, the termination of the first part of the path is marked by a detonation, the so-called explosion, the vacuum inside of the fireball being suddenly filled by the surrounding air.

The Stannern stone seems to have passed through the air with its rounded side first, and shows over its surface effects resulting from a uniform action of the atmosphere upon it whilst the crust was in a viscous state. The lustrous crust is surrounded by a protruding gibbosity; the stone had sharp edges which in the foremost direction of the meteorite were melted off and blown towards the back part. The time of the passage through the air generally lasts only a few seconds. The rising temperature producing the crust belongs to this period, since the stone came from the planetary space with a temperature of 100° C. below freezing-point. Some meteors get heated very rapidly; masses of iron will sometimes get red-hot whilst one composed of some other substance will be quite cold inside; and as soon as the detonation takes place, and the fireball disappears, the inside and outside temperatures of the meteorites are soon counterbalanced and the crust rapidly cools, especially at a height where the temperature is very low.

The stone of Gross-Dwina, which in its general character is allied to those of Timochin, Zebrak, and Eichstadt, shows a great dissimilarity on its two principal planes, one being smooth, and the other rough. The form is that of a fragment altered only on its surface. Characteristic of this meteorite is a ridge which passes over the "head" of it; and corresponding with it there was one passing over the back part of it. The roundish spots where a melting off has commenced have a striking resemblance to the impressions of figures in dough; they are generally to be found on the side best protected during its passage.

3. *St. Denis-Westrem.*—At a meeting of the Imperial Academy of Vienna on October 4th, 1860, Director Haidinger gave an account of this meteorite.

The fall took place without detonation, and only a slight noise was heard similar to the rattling of carriages, on June 7th, 1855, $7\frac{3}{4}$ P.M., near the town of St. Denis-Westrem, $2\frac{1}{2}$ miles from Ghent.

It fell thirty paces from a man and woman, penetrated the ground about 2 feet, and was immediately dug up; it was hot, of a bluish-black colour, and smelled sulphurous. It weighed 700·5 grammes, its sp. gr.=3·293. Its form was similar to that of an "ananchites," having a flat elongated base and an arched enclosure. It has the character of a real fragment, and is encrusted all over. The crust is uneven on one side, whilst the other is more even and equally rounded, the edges between the rough surface and rounded planes being well marked.

The stone resembles those of Reichenbach's second family, "somewhat bluish stones." The stone contains disseminated iron and pyrrhotine,—the latter, sometimes filling up vein-fissures, giving it the character of a fragment from a very large mass—a mountain of rock. Disseminated through the whole mass were spots of iron-rust and crystalline globules, which leave impressions when falling out of the brittle mass.

4. *Indian meteorites.*—At the meetings of the Imperial Academy of Vienna, on June 8th, November 3rd, and the last one in the year 1860, M. Haidinger gives accounts of the Calcutta meteorites which had been acquired a short time previously by the Imperial Cabinet of Minerals.

(1.) The meteorite of Shalka fell in a rice-field about 80 yards south of the village, on November 30th, 1850, a few hours before sunrise; it was witnessed by two persons. The noise, compared with thunder, was not very loud; the stone penetrated 4 feet into the earth; fragments were found 3 feet deep in a circle of 20 feet radius. Only one stone fell, which may have been 3 feet long. It came from the south, at an angle of about 80°. The stone is very peculiar; the white portions resemble pumice, whilst the darker resemble pearlstone; it is friable like cocolite. The real fracture shows greasy lustre. It does not contain any metallic iron. It belongs to Reichenbach's first family, first group.

(2.) A fall of meteorites occurred on December 27th, 1857, at Quenggouk in Pegu; three stones, evidently fragments, were found five and ten miles apart. It had the appearance of a large umbrella in flames, as observed at a place ninety miles south of Quenggouk, at an altitude of 40° or 50°, giving a report like that of a monster gun. Another observation, taken on board the 'Semiramis,' about 200 miles S.E. of where it fell, describes it as having had at first the appearance of a large star increasing to three times the size of the moon, leaving behind a long tail, and falling towards the east. Haidinger gives the height at 80 or 120 miles.

(3.) This fall occurred at Dhurmsala in the Punjab, accompanied by a tremendous noise, the earth being shaken in convulsions. The direction was N.N.W. to S.S.E. The fragments penetrated to a depth of 1 to $1\frac{1}{4}$ feet; the largest weighed 320 lbs. The fall took place July 14th, 1861.

(4.) The fall of meteorites at Futtehpore on November 30th, 1822, is mentioned.

(5.) The real locality of a stone which was found in 1846, and which Piddington supposes to be from Assam, is not known. It is beautifully marbled, very solid, and resembles the meteorites of Seres, Barbotan, and others of the third family of Reichenbach. The crust is dark greyish-black, sp. gr. at 17° R.=3·792.

(6.) The fall of the Segowolee meteorites took place on March 6th, 1853. All the stones were pyramidal, and weighed from $\frac{1}{4}$ to 4 lbs. The crust is very thin, not over $\frac{1}{4}$ line in thickness, dark-reddish brown. The whole condition gives proof of a slight fusibility.

No. 5. *The meteoric iron from Tula, Russia.*—In the year 1846, a mass of iron of over 15 puds (542 lbs.) was found $4\frac{1}{4}$ miles from Marunskoje. Dr. Auerbach has given us the first notice of it. The principal mass consists of iron with pieces of meteoric stones imbedded. They are real fragments separated from larger masses by mechanical force. The metallic nickeliferous iron formed veins in the granular rock, the latter consisting of a mixture of metallic iron and a silicate of iron and magnesia. The Widmanstätten's figures in this iron show a striking resemblance to those of Burlington, Owego County, New York.

Judging from analogies observed upon our earth, Haidinger has come to the conclusion that before the stones were imbedded in iron they were united as portions of real rocks in one and the same celestial body, from which they came to our earth.

The forms of the larger and smaller lumps show, however, many peculiarities which require a more thorough investigation.

The meteoric iron from Nebraska was obtained from N. Holmes, Esq., of St. Louis. The original mass weighed 35 lbs., and was found 25 miles west of Fort Pierre. A segment of the Vienna specimen cut parallel with a octahedral plane showed striæ of half a line in width, intersecting at angles of 60° and 120°, with the triangular and rhombic intervals between the enclosing ledges of schreibersite covering the whole etched surface. The Widmanstätten's figures show a close resemblance to those of the Red River iron preserved in the Yale College cabinet.

Fall of the Meteor of Parnallee, near Madura, in Hindostan. By W. Haidinger, Ordinary Member of the Imperial Academy of Sciences. (Presented at the sitting of February 7th, 1861.)—

A communication from Professor Silliman causes me to report on the fall of a meteor which occurred on February 28th, 1857, about noon, near the village of Parnallee, south of Madura, at the northern extremity of Hindostan. Mr. Silliman wrote to me that the meteorite (which is deposited at Western Reserve College, at Hudson, Ohio) had, according to the chemical analysis made by Dr. Cassels, of Choktaws, Ohio, been found to contain only 3 per cent. of metallic iron, and amongst it 17 per cent. of nickel. He expects to receive a fragment of it, and they also intend to send us a portion of the latter. Now I was enabled, in answer to the above, to communicate several statements which had not been known to Mr. Silliman.

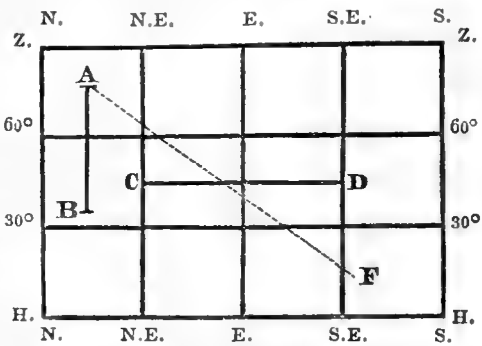
Already in the summer of 1858, I read the excellent account drawn up by the head of the American Mission at Madura, Mr. H. S. Taylor, respecting the fall of the meteor itself,—two stones of immense size having fallen, one weighing 37 lbs. and the other weighing four times as much, or 148 lbs. This account is given in the 'Transactions of the Geographical Society of Bombay' for 1857; also the 'Athenæum' [probably the Madras 'Athenæum'] contained a notice of it. Only in 1859, when our operations commenced for the increase of the collection of the meteorites of the Imperial Mineral Cabinet, I wrote to Dr. G. Buist, secretary of the Society and editor of the Bombay *Times*. But Buist was just in the act of removing to Allahabad, and could not intercede in the matter; so then I applied to Mr. Taylor himself, and I also wrote to Madras. It now became evident that the larger stone was being sent to the Museum of Madras, but that the one weighing 37 lbs. which he received back again, had been sent to Hudson in America. Mr. Taylor was kind enough to give me the address of Professor Ch. A. Young, to whom I then wrote directly, and who already a fortnight ago had the kindness to promise us a beautiful specimen of this meteorite of Parnallee, which I shall in due course place before the students and fellow-members of my class. I could even have delayed my present communication respecting the fall itself until then, as no accounts of it are to be found in any European book.

According to Mr. H. S. Taylor's account, the two stones fell a little north-east of the village of Parnallee, 9° 14′ N. and 78° 21′ east of Greenwich, according to the map of the Government Survey. According to the direction of the hole which they made in striking the ground, they came from about N. 10° W. inclining to the perpendicular at an angle of from 15° to 20°, the smaller one nearly perpendicular. They were fixed in the ground in such a manner that that part of the surface which was the most rounded or convex was placed towards the bottom; this was, as Mr. Taylor expressly states, in accordance with the centre of gravity, and therefore the very position which the meteorites had to take in passing through the resisting atmosphere. The larger stone struck into the ground in a ploughed field to the depth of 2 feet 5 inches, the smaller one to the depth of 2 feet 8 inches; the smaller one had not the appearance as if it were a fragment of the larger one; the specific weight of the smaller one is, according to Taylor, 3·3. The larger stone when grown moist showed on the round surface a crack, which afterwards became still wider, perhaps in consequence of oxidation: the report caused by its fall was considered terrible by the natives, like two thunder-claps as one stone struck into the ground after the other; and the echo lasted for some time, although that was not so loud. They were heard as far as Tuticorin, to the south, on the coast of the Gulf of Manaar, at a distance of forty English miles; very loud at Madura, which is sixteen miles off.

Several persons were near the spot when the fall took place, and yet nobody saw either of these large bodies as they fell, owing, as they think, to the velocity of the motion. A cloud of dust rose from the places where they struck the ground; Mr. Taylor could still see the hollow which had been caused in the compressed earth. Up to the 21st of April, when he examined the locality and obtained the stones, there had been no fall of rain.

Their shape, although somewhat irregular, is compared to large cannon-balls covered with a black crust as if smoked, in the interior like granite, with particles of iron. Taking into account the short time during which the phenomenon lasted, the fact of the stones striking into the ground without any one having seen them approaching in the atmosphere, all this might tend to show that the ground was struck by a real "horizontal shot."

M. Haidinger, of Vienna, recommends as convenient in certain cases that the observed apparent tracks or paths of meteors should be approximately mapped down, on the principle of a Mercator's chart, and that the altitude and geographic orientation should be carefully inscribed in a diagram like the annexed figure, in order afterwards to be able, by comparison with the precise time, hour, day, and year, to find the point from whence they were coming. A B would be the track of a meteor seen



first at A at an altitude of 75° in the N.N.E., and disappearing or bursting at an altitude of about 40°; while C D might denote a meteor that seemed to move horizontally from 45° N.E. to 45° S.E., its true course being from north to south, but visible from the side. Similarly a meteor appearing at A might move obliquely downwards to F, disappearing at 15° in the south-east, and be represented by a line joining those two points.

No. 6. Extracts from a letter from Professor Cocchi, at Florence, to Mr. Greg.

"At 9 o'clock P.M., 25th July, 1847, when I was riding from Prato to Florence with a relation of mine and a man-servant, an enormous igneous body appeared over our heads, rushing towards the north. Our horses were much terrified, and we saw everything around us as if it were daylight. We heard no detonations after the disappearance of the meteor, which was many times larger than the moon, but a kind of hissing sound, not unlike the flying of some bird. I think it must have passed very near us; at least, we experienced a sense of heat at the time, and when its light was extinguished we could for some seconds distinguish in the air a phosphorescent light.

"On the 4th or 5th of October, 1859, I was walking with my two brothers near our country seat of Tarrarossa, at about 8 P.M., when suddenly our attention was attracted by a splendid fire-ball flying rapidly in a S.W. direction; the apparition lasted some seconds, when it disappeared beneath the horizon. I heard no detonation, but my brothers stated they heard it in spite of the great distance; if so, the fragments of this meteoric body fell down into the sea, not many miles from Tarrarossa.

"My friend Professor Compani, of Siena, wrote to me some time ago about a similar event which terrified and dismayed Siena, and made many of its citizens leave their shaking houses in a great hurry. He says, 'In December last (1860), about the 16th day of the month, an enormous bolide traversed the sky over Siena, which a few minutes afterwards made a terrible noise in its progress; it left in its track many sparks. Judging by the ear, the explosion must have taken place between Asciano and Buonconvento; some indeed aver having seen fall, in some places, sparks of fire; nothing, however, was found."

"Florence, August 8th, 1861."

No. 7.—Extract from Dr. Buchner's Work on Fire Meteors.

"It has been contended by many, in opposition to Chladni's (1820) opinion, that large fire-balls are totally different from shooting-stars, that they are quite a different class of bodies. Davy, L. Smith, and Shepard, who are the advocates of this opinion, among other things insist upon this point, that if both are analogous bodies there would also, at the time of the periods for shooting-stars, especially in the months of August and November, necessarily fall more aërolites. They contend that no instance of any observation made could be stated, that whenever an aërolite has been seen, it equally made its appearance by itself alone, and not in connection with other meteors.

"Even though the rich November streams of 1779, 1830, and other years have not actually been shown to have been abundant as regards meteorites, yet the recent modern comparisons made are such as may cause us to fairly admit the homogeneous nature of the two phenomena. Baumhauer compared the fire-meteors for the single days in the year, as also has Rudolph Wolf at Zurich. Accordingly, leaving out the days on which no fire-meteors or a few only were observed, we have the following days as having been particularly plentiful as regards large fire-balls and falls of meteor-stones.

	Baumhauer.	Wolf.	Greg*.
January 2 ...	6	5	11
„ 10 ...	0	5	8
„ 13 ...	6	0	6
Feb. 4 ...	0	5	3
„ 6 ...	7	7	7
„ 18 ...	6	5	8
March 1 ...	5	5	9
„ 8 ...	5	0	6
„ 31 ...	0	5	4
April 9 ...	5	5	5
„ 10 ...	4	5	5
„ 19 ...	4	5	7
May 17 ...	5	0	5
„ 22 ...	6	0	4
June 7 ...	0	5	6
July 17 ...	10	7	11
„ 29 ...	6	8	10
August 3 ...	6	5	12
„ 5 ...	4	5	10
„ 6 ...	5	0	6
„ 7 ...	5	6	12
„ 8 ...	4	5	6
August 10 ...	7	11	11
„ 11 ...	2	5	10
„ 12 ...	5	0	15
Sept. 1 ...	0	5	7
„ 10 ...	7	0	9
„ 13 ...	6	6	7
October 1 ...	6	6	11
„ 3 ...	0	5	7
„ 23 ...	5	0	8
Nov. 9 ...	4	6	13
„ 11 ...	0	5	12
„ 12 ...	8	7	11
„ 13 ...	9	9	16
„ 16 ...	0	15	10
„ 19 ...	5	8	14
„ 29 ...	5	5	9
Dec. 2 ...	4	5	6
„ 8 ...	4	7	12
„ 11 ...	0	7	15
„ 13 ...	6	5	10
„ 30 ...	0	5	8

"Mr. Greg himself is, however, favourable to the notion that the larger and probably aërolitic class of fire-balls, *e. g.* such as those seen in July or at long and uncertain intervals, are dissimilar in character and orbit to the small and more common sporadic meteors. It would be, however, premature as yet to offer any dogmatic opinion on this point.

"Upon the whole, it may be taken with some confidence that there are periods when a larger class of fire-balls and falling stones are more numerous than at others; and it is rather singular that this class does not seem to be so abundant at the August epoch as might have been expected; in fact, they seem to be more numerous towards the end of July and the first three or four days in August, the great epoch being the 9th and 10th days."

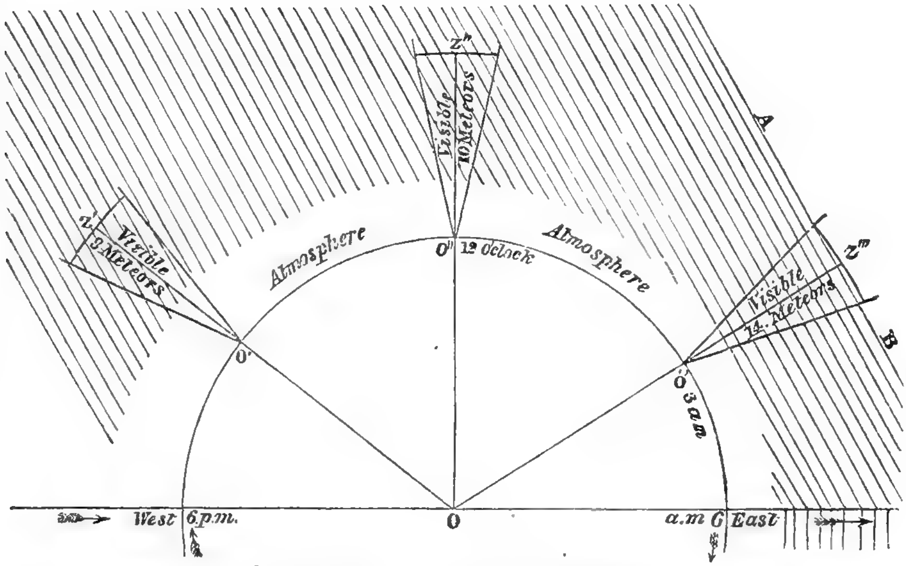
No. 8.—A. In the volume of the Dublin British Association Report, page 143, it states that M. Coulvier-Gravier did not assign any reason why more meteors are seen in the east quarter than the west quarter of the heavens. But Mr. Bompas seems to have given a very neat solution (page 144), that is, on the supposition that all meteors are equally distributed in space, not only the reason of that, but why we see more towards 6 A.M. than at 6 P.M. Probably his reason is a correct one, and perfectly sound; there may possibly be others.

In diagram No. 1 let it be supposed there are meteors, AB, crossing obliquely and in one direction; and it is possible the majority of them may really do so (or the obliqueness of their paths may be considered the resultant, or apparent resultant, of the combination of the earth's motion in her orbit and of the meteor's motion). If the average of meteors pass the earth's orbit obliquely, such a result as fig. 1 shows might likewise explain how it is we should see more meteors in the early morning than in the evening, and also a tendency to see a larger proportion in the east than in the west.

* The numbers here appended are taken from Mr. Greg's Catalogue published in the Oxford Reports for 1860, given here for the sake of comparison.

The time when most meteors are seen would probably also be the time when we should observe them most nearly moving at right angles to their true directions.

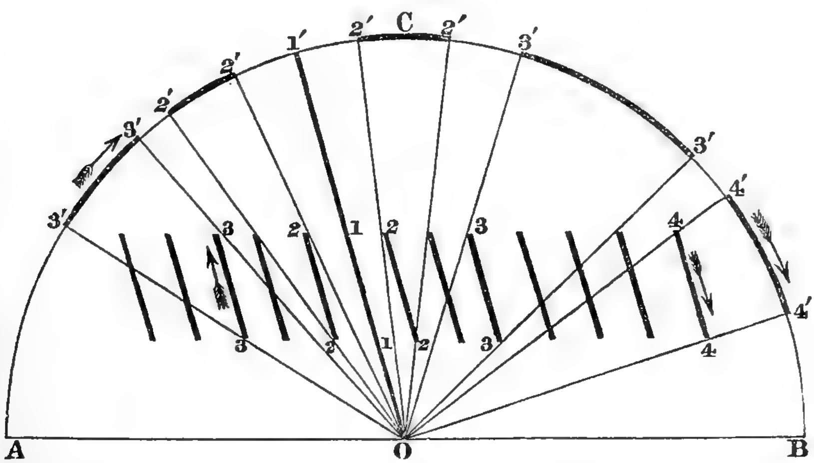
Fig. 1.



O, observer. z″ observer's zenith.

B. Olmsted, in his 'Mechanism of the Heavens,' a popular little hand-book, gives a diagram (fig. 2), the object of which is simply to show the reason

Fig. 2.



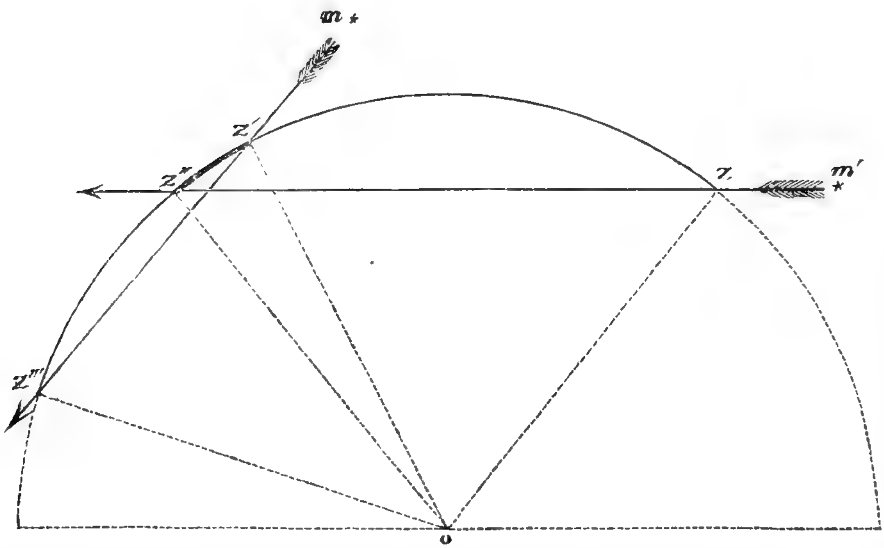
Let ABC be the vault of the sky, and O the observer. Let 1, 2, 3, 4 represent parallel lines towards the earth. A meteor passing through 1′1, or axis of vision, would appear stationary at 1′. A body falling at 2 2 would seem to describe the short arc 2′ 2′, or a concave path in the sky; and similarly a body falling through 3 3 would appear to describe the larger arc 3′ 3′, &c. Hence those meteors which fall nearer the axis of vision would describe shorter arcs, and move slower, while those further from the axis and nearer the horizon would seem to describe larger arcs, and move with greater velocity. The meteors would all seem to radiate from a common centre 1′, which was the case on Nov. 13th, 1833.

why there should appear to be a radiant point for shooting-stars, and why near that point in the heavens no meteors or very few were seen, or if seen why their tracks near that point appeared so short, and in other parts longer (and why perhaps also, on the principle of fig. 1, more numerous towards the east).

C. May it not be presumed that the majority of meteors seen at night must be coming towards the sun, their average distance from us while visible being not more than 50 or 100 miles; while the earth, being 7000 miles in diameter, would consequently intervene as a shield in keeping out of sight the majority of meteors coming directly from the sun, and whose paths we come across? If two meteoric stones struck opposite sides of the earth at the same moment, 12 M., we might almost presume one was going to, and one from, the sun. It would certainly be interesting to know whether the majority of meteors are going to or from the sun, or passing the earth's path at right angles, obliquely or parallel.

D. It is quite possible that two shooting-stars, m and m' (fig. 3) might each

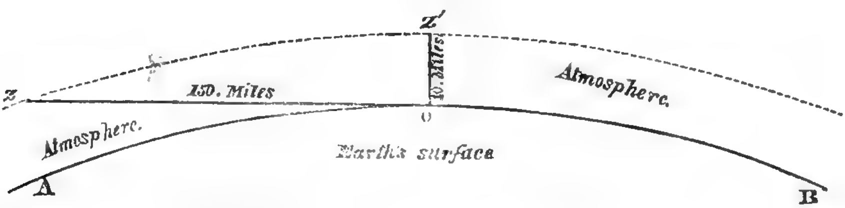
Fig. 3.



appear to project on the sky apparently a similar and common track Z' Z'', though in reality moving nearly at right angles to each other's direction, the only difference being a shorter or longer visible path. The angle might even in some cases perhaps be more than 90°, and the two meteors coming obliquely and from opposite directions; yet an observer at o would be unable to tell in which direction the meteor moved; in either case it would seem to pass downwards in the ordinary way. This helps to show the difficulties in these cases, and to negative results in catalogued descriptions giving the directions meteors have appeared to move.

E. Why is it that meteors are so seldom seen near the horizon even on a clear night? Is it because of the atmosphere, or that they would necessarily in that position be too far off? If they do not come nearer the earth's surface than 40 miles without being consumed or extinguished (fig. 4), we should

Fig. 4.



more frequently see them at Z', only 40 miles off, than at Z, 150 miles distant;

and as that possibly (say 150 miles) is above the average limit of visibility, we perceive perhaps why we do not often see shooting-stars very low down in the horizon. It might be desirable as frequently as possible to record the length of the visible arcs described by shooting-stars, and the time in moving along these arcs, to see if the average varies at different hours of the night, for different quarters of the heavens, as well as at different times of the year.

F. In making averages from tabulated statements, say for a whole year, in reference to meteors, the enormous *preponderance* of meteors seen on a few days only, viz. August 9–12 and November 10–13, which, being periodic and generally moving in parallel right lines and in one direction, must have a tendency to disturb to some extent any attempt to fairly tabulate the more scattered observations during the rest of the year.

However, Olmsted's account of the great meteor-shower in 1833 seems to prove that there were then hardly any known meteoric appearances (whether as regards tracks, luminosity, size, direction, velocity, &c.) which were seen on that night that one is not accustomed to see or read of at all other times put together. Most, too, were seen in the east, and moving from thence towards the north-west; so that we might not unreasonably infer that most shooting-stars at all times much resemble each other.

G. Humboldt describes a shower in Mexico, on the night of the 12th of November, 1799, thus:—"They *rose* from the horizon between the east and north-east points, described arcs of unequal magnitude, and fell towards the south." They were seen in many other parts of North and South America on the same night, and in Labrador they were observed to fall down towards the earth.

No. 9.—*Meteors of August* 1860.—At Paris, Coulvier-Gravier states the mean hourly number at midnight, of shooting-stars, on August 9th was 62; on August 10th, 54; or about ten times as large as in the middle of July. At Rome, the observations of Secchi gave a decisive maximum on the 10th of August. The observations of Bradley at Chicago, and of Herrick at New Haven, Connecticut, U. S., gave the increase of shooting-stars on the nights of the 9th and 10th of August, 1860, at about six times the common average, and their apparent direction nearly all from the vicinity of the constellation Perseus.

At Yale College, Connecticut, U. S., 565 falling stars were seen on the night of the 9th of August and morning of the 10th, between 10 P.M. and 3 A.M., by six observers. The majority first appeared in the south-west quarter of the sky, with a westerly direction; several left behind luminous trains, but none appeared to explode: none seemed larger than Venus; three-fourths conformed to the usual radiant in Perseus.

Meteors of November, 1860.—In the United States a slight tendency to an increase over the average was noticed; the conformable ones coming from the usual point in Leo, exactly as in the great shower of November 13th, 1833. Professor Twining, of New York, observed on the morning of the 14th fourteen meteors, of which nine were conformable and five not conformable.

The total number actually observed by Professor Kirkwood and five assistants in Indiana, on the night of the 12th of November and morning of the 13th, in six hours, amounted to 381, distributed as follows:—

From 10 to 11 P.M.	45	From 1 to 2 A.M.	66
From 11 to midnight	66	From 2 to 3 A.M.	90
From midnight to 1 A.M.	68	From 3 to 4 A.M.	46

The Shooting-stars of August 1861.—"M. Coulvier-Gravier has forwarded to the French Academy his annual report on this subject, especially for August 9th, 10th, 11th, but including the time from July 15th to August 14th. The average number of these meteors per hour, at midnight, for July 15th, 18th, 19th, was 6·5; for July 28th, 29th, 30th, was 13·6; for July 31st, August 1st, 2nd, was 22·4; for August 4th, 5th, 6th, was 27·2; and for August 9th, 10th, 11th, was 50·8. For August 12th, 13th, 14th, the average per hour was only 24·4. M. Coulvier-Gravier's calculations show that the year 1858 marked the term of the decrease of the number of these phenomena since 1848—the epoch of their greatest number. Since 1858 their number has gradually risen; and we may hope therefore for the reappearance of the meteoric splendours of August.

Further observations on these brilliant phenomena, by Father Secchi, at Rome, appear in the *Cosmos*. On August 9th, forty shooting-stars were seen between 9 and 10 o'clock P.M.; on August 10th, between 9 and $10\frac{1}{2}$, 133 appeared; and in the same period of time on August 11th, the number fell to seventy. Secchi therefore concludes that these phenomena are not meteorological, but cosmical. He adds that he considers the most rational explanation to be the admission that the sun is surrounded, in addition to the comets and planets, by a ring formed of small bodies, which cuts the ecliptic at the point where the earth is situated on August 10th; and as every year the earth returns to this point on the same day, and as, also, this point may correspond with a condensed portion of the ring, we therefore see a great number of these small bodies, attracted by the mass of the earth, fall into it, and become inflamed by contact with our atmosphere. This theory he considers to be confirmed by the constancy of their directions, which are *parallel* and *contrary* to that of the earth in its orbit on that day."—*Extract from the 'Illustrated London News' of September* 14, 1861.

Note.—In generalizing from observations on the August periodical meteors at any one spot on the earth's surface, it should be remembered that the hourly numbers seen vary considerably with the locality. In 1833, the great and wonderful display of meteors on November 13th was almost entirely confined to the area of the United States; and the total numbers per hour observed of late years simultaneously at different stations appear to vary. Secchi's theory of the ring of meteors is pretty much that which Sir John Herschel advanced some time ago, and seems to be well worthy of acceptance; their orbits must in all probability be more elliptic than that of the earth's orbit.

August Meteors.

"SIR,—The August meteors this year have been more numerous than usual. Last year, both at the August and November epochs, the sky was completely overcast; so that it was impossible to determine their number, or, in short, to make any observations at all. During the August epoch of the present year (1861), although there was much cloud at times, there were periods of clear sky which enabled me to make some good observations.

"Several letters in the *Times* have given α Persei as the point of divergence of the August meteors; this is not correct, as the point is very near η Persei: a line drawn from η Persei to α Cassiopeiæ will pass through this point at a distance of less than 2° from η Persei. The meteors increased in number as the night progressed, *i.e.* there were more about 2 A.M. than at 10 P.M.

"The nearer the meteors were to η Persei, the shorter were their paths; those with long paths were mostly 45° or more from this point. Those near Perseus were longer in moving over 1° of space than those at a distance from this point.

"The meteors about Perseus were mostly small, some only just distinguishable, the larger ones were usually 40° to 60° from η Persei.

"A meteor, almost upon the point of divergence, scarcely moved amongst the stars. The year before last I saw one *exactly* on this point; it became visible, increased in magnitude, and then disappeared *without moving*.

"No meteor was observed to move *towards η Persei*, all moving away from that star. On the 14th there were a number of meteors discordant, but on the 11th and 12th scarcely one whose path produced backwards would not have touched the point near η Persei.

"There was a great similarity in the meteors. Nearly all had tails or streaks which lingered for a short time after the meteors themselves had vanished, and nearly all were of the 2nd to 4th magnitude.

"A meteor seen through a telescope of $2\frac{1}{2}$ inches aperture, with a power of 20, had a decidedly planetary appearance, the tail being *phosphorescent-looking*, not fire-like. The duration was too brief to make any very careful observations; and the meteor itself was small, viz. 3rd magnitude.

"The weather on the above days was warm, and the wind between W. and S.W.

"E. J. LOWE."

"Observatory, Beeston, August 20th, 1861."

No. 10.—M. Le Verrier has just applied the results of his researches on the four planets, Mercury, Venus, the Earth, and Mars, to the rectification of existing astronomical tables. From the perturbations observed in the orbits of these planets, he has come to the conclusion that there exists in our system a considerable quantity of matter which has not hitherto been taken into account. In the first place, he supposes that there must exist within the orbit of Mercury, at about 0·17 of the earth's distance from the sun, a mass of matter nearly equal in weight to Mercury. As this mass of matter would probably have been observed before this, either in transit over the sun's disc or during total eclipses of the sun, if it existed as one large planet, M. Le Verrier supposes that it exists as a series of asteroids. Secondly, M. Le Verrier sees reason to believe that there must be a mass of matter, equal to about one-tenth of the mass of the earth, revolving round the sun at very nearly the same distance as the earth. This also he supposes to be split up into an immense number of asteroids*. Thirdly, M. Le Verrier's researches have led him to the conclusion that the groups of asteroids which revolve between Mars and Jupiter, and sixty of which have been seen, and named, and had their elements determined, must have an aggregate mass equal to one-third of that of the earth. He thinks it not at all unlikely that similar groups of asteroids exist between Jupiter and Saturn, between Saturn and Herschel's planet, and between the latter and Neptune.

Haidinger reports that M. Julius Schmidt, of the Royal Observatory, Athens, is continuing his observations, it is said, on the phenomena presented by the luminous trains of meteors, with interesting results. It is intended to publish some particulars in the next year's report on luminous meteors.

The following recent publications on meteoric literature may be especially noticed.

1. Versuch eines quellenverzeichnisses zur Litteratur über Meteoriten: von Dr. Otto Buchner von Giessen. Published at Frankfort-on-Maine, 1861.

2. By the same author, and a very valuable and comprehensive work,

* It is very possible the meteorites which from time to time fall to the earth may be the representatives of this group of Le Verrier's.

Die Feuermeteore, insbesondere die Meteoriten historisch und naturwissenschaftlich betrachtet. Giessen, 1859.

3. Kengott über Meteoriten. Zurich, 1860.

4. Recherches sur les Météores et les lois qui les régissent: par M. Coulvier-Gravier. Paris, 1859.

5. Ueber den Ursprung der Meteorsteine: von P. A. Kesselmeyer. Frankfurt am Main; accompanied with a most valuable catalogue of meteorites and 3 maps.

Report on the Action of Prison Diet and Discipline on the Bodily Functions of Prisoners.—Part I. *By* Edward Smith, *M.D., LL.B., F.R.S., Assistant Physician to the Hospital for Consumption, Brompton; and* W. R. Milner, *M.R.C.S., Surgeon to the Convict Prison, Wakefield. With Appendices.*

The Committee appointed at the late Meeting of the British Association, "to prosecute inquiries as to the effect of prison diet and discipline on the bodily functions of prisoners" have the honour to state that they have fulfilled the task assigned to them so far as time and opportunity have permitted; but they regret that, on the one hand, they have not been able to gain access to some information which they required, and, on the other, that the great extent of the inquiry has prevented the completion of the series of researches, to which they attach great importance. Hence they purpose on the present occasion to present the first part of their report, which will include some general remarks on the management and present system of dietary and punishments in county gaols, with the various researches which they have hitherto made into the influence of prison discipline over the weight of the prisoners, the precise influence of prison punishments over the respiratory function and the elimination of urinary products, with the ordinary discipline of the gaol and with certain forms of labour.

In conducting their researches the Committee have had in view not only the letter but the spirit of the resolution by which they were appointed, and have understood their prime duty to be the elimination of important physiological facts, for which the discipline enforced in gaols offers good opportunities. Whilst, therefore, determining the various matters which will be discussed in this the first part of their report, they have also been very desirous to investigate some of the more recondite questions in nutrition—as, for example, the relation of the nitrogen ingested to that egested; and having obtained the valuable aid of Mr. Manning in making chemical analyses, they have concluded two extended series of inquiries at Coldbath Fields and Wakefield Gaol, in which the relations of the ingested and egested nitrogen have been largely inquired into; but the great care required in this part of the inquiry, and the very extended character of the subject, have induced the Committee to withhold the results hitherto obtained until another occasion, when, should they be permitted to do so, they will present them with additional inquiries in the second part of their report.

With these explanatory observations, the Committee proceed to state the results of their inquiries, and, first, to offer some general remarks upon the management, the dietary, and the punishments in county gaols.

GENERAL OBSERVATIONS.

The Management of County Gaols.

The management of county prisons is placed almost exclusively in the hands of the County Magistracy, and is therefore liable to as much diversity as there are Boards of Visiting Justices. The Secretary of State must approve of any "rules" within the meaning of the Act, and he also approves of the scale of dietary; but hitherto he has not exercised his power to insist upon uniformity in dietary; and hence, within certain limits, the Visiting Justices regulate the dietary. There are also three* (nominally four) Inspectors of Prisons for England, appointed by the Home Secretary, who visit the prisons periodically, and report their condition to the Home Office, and also suggest to the Visiting Justices from time to time such changes as they may think to be desirable; but they have no power to interfere with the orders of the Visiting Justices, if the orders are within the provisions of the law and the "rules" of the prison. Hence the sole authority in county gaols under normal conditions is the Board of Visiting Justices. There is a scheme of dietary which was recommended by the Home Office, under the administration of Sir James Graham; but it is not always adopted, and there is no plan whereby uniformity is ensured.

It thence follows that there is the greatest diversity in the gaols both as to punishment and dietary, and to a consideration of this your Committee directed their first attention.

A "Return of Dietary for Convicts, &c." was issued in 1857, which gives the dietary in the various convict and county prisons, but there has not been any general return obtained as to the nature of punishment inflicted, and the plan pursued in carrying out hard-labour sentences. As it was very desirable that some authorized information upon these points should be introduced into this report, Mr. Bazley, M.P., most readily and kindly undertook to move for one in the form given in the Appendix (II.), but, after having it entered upon the "Orders for the day," he failed to obtain the sanction of the Government, and withdrew it. The Committee venture to hope that the British Association may think this of sufficient importance to lend their aid in obtaining it during the next Session of Parliament, and would remark that, although the proposed return has a formidable appearance, its tabulated character tends to reduce, and not to increase, the expense of printing and the labour of writing.

Punishments.

In the absence of this authorized return, the Committee quote the results of an inquiry previously made by Dr. Smith, who addressed a letter to the governors of upwards of sixty county gaols, and was favoured with their replies. The general expression of the results is as follows :—

"In our county prisons some find no labour at all, others only that of ordinary trades, others have crank-labour † alone, others treadwheel-labour alone, whilst in many one of the two, or both of the two latter forms of hard labour are conjoined with some kind of trade. In many the treadwheel and crank are unprofitably employed, whilst in others they are used as mills or pumps. In some, women even work some kind of crank and the treadwheel.

* The number is now reduced to two.—Feb. 1862.

† When the term "crank" is employed in this report, it is intended to indicate the instrument turned by hand, and technically known as the "hard-labour crank." This differs from other hand cranks only in that it is purposely arranged for non-remunerative work, and indicates the number of revolutions which have been made in a given period.

In some the treadwheel and crank are exceptional employments; in others they are universally used for a small part of the sentence; whilst in a third class they are the constant employments during the whole term of imprisonment. In most gaols they are chiefly employed for short sentences, and therefore for small crimes, and with insufficient food, whilst the light occupations are reserved for long sentences, with greater crimes, or frequent repetition of crime, and sufficient food. In some they are worked for an hour without intermission; in others thirty, twenty, fifteen, ten, and down to four minutes only at a time. In some they are enforced for three hours daily, and simply as exercise; whilst in others the labour endures ten hours. In many, boys of fourteen years of age work the wheel and the crank; whilst in others, able grown men make shoes or pick oakum only. In some the ordinary rate of the ascent on the treadwheel is fifty-six steps of 8 inches each per minute, whilst in others it is so low as thirty. In some the ordinary pressure on the crank is seven pounds; in others, twelve pounds,—the pressure being certain, and demonstrated by weights in one, and uncertain, depending upon the turns of a screw in another. In some the ordinary number of revolutions per day is 14,400; whilst in others, in which the crank is still the chief instrument of punishment, it varies from 13,500 to 7000 or 6000, at the discretion of the surgeon, the prisoner being in all these instances without disease. In some the day's work may be performed in any part of the twenty-four hours, with the index of the instrument in sight of the prisoner; whilst in others, as the New Bailey, Salford, it must be performed before the night and with the index outside the cell, so that the prisoner is unable to ascertain, from time to time, how much labour he has yet to perform. In some, pumping is employed for an hour only, and even during that short period, as at Reading, there is no method of determining if any individual prisoner is labouring or not; whilst in others, the labour is for the whole day, pumping water into the sewers.

"Oakum-picking is no labour in one prison, and hard labour in another; and in the latter it is two pounds for a day's work at Wandsworth, and three pounds at the Coldbath Fields, whilst it is five pounds at a workhouse; and the rope itself differs greatly in the amount of labour which is required to tear it to pieces. In some the prisoner, by good conduct, obtains lighter labour, a commendatory badge, and a pecuniary reward; in others it is treadwheel labour from the beginning to the end of the imprisonment, whilst in many, as at Wandsworth, the change of labour is due neither to crime, sentence, nor conduct, but simply to the variation in the number of the prisoners.

"In addition to all this, in some prisons the separate system is strictly enforced and a mask worn, whilst in others hundreds of prisoners sit together in the room picking oakum; and, finally, in some the cat is so heavy, and the officer's arm so strong and willing, that the prisoner is for a time made insensible to pain after a few strokes, whilst in other prisons it is so light as to leave very little evidence of its use."

Hence it appears that the utmost diversity exists in the different county prisons as to the instruments of punishment employed, the condition in which they are kept, the amount of labour which they exact, the amount of a day's work, the system of progressive change in the use of the various means of enforcing labour, and, in fact, in all that concerns the carrying out of the sentences of hard labour.

Dietary.

In reference to dietary, the diversity is even more striking; for so various are the schemes contained in the "Return of Dietaries for Convicts, &c.,"

referred to, that it is impossible, by any method, to give an analysis of the amount of nutriment which they supply. An abstract of the most noticeable parts of the return is given in the Appendix (I.); and it is proposed to state in this place only a few general facts.

It is customary to provide several scales of dietary, increasing in the nutriment supplied according to the duration of the imprisonment; so that with the shortest sentences, as three, seven, or fourteen days, the only food given is bread and gruel*; whilst for prisoners condemned to long terms of imprisonment the diet is generally an abundant one of meat, vegetables, bread, and gruel. The terms of sentence to which these several classes apply vary in the different gaols; but usually a sentence of four months carries with it the highest scale of dietary. In nearly all gaols the prisoner is on entrance placed upon his proper scale of dietary; but in the Kendal, Carlisle, and other prisons he begins with the lowest scale, and gradually ascends as his duration of imprisonment continues.

It is also usual to vary the dietary from day to day; so that there is a considerable daily variation, not only in the kind and quantity of food, but in the amount of nutriment supplied. There is commonly an increased dietary given to those who are condemned to hard labour; but the modes in which sentences of hard labour are carried out differ so much, that this is practically valueless. There are gaols in which the treadwheel is worked for short periods with a dietary of bread and gruel only*. But in none is there any attempt to estimate in a scientific manner the amount of increase of nutriment which is proportioned to the increased labour. Usually there are three meals a day allowed (at St. Albans there were only two); and of these the first and last consist commonly of bread and gruel. The amount of flesh supplied in the highest scale of dietary varies greatly, as, for example, from 6 ozs. of cooked meat without bone in the Middlesex and Brecon Prisons, and $7\frac{1}{2}$ ozs. of uncooked meat with bone at Wakefield, to (until very recently) an entire absence of that food in the Cardiff Gaol. Very small quantities of milk, cocoa, oatmeal, cheese, and tea are given in a few gaols; but commonly the dietary consists of meat, soup, potatoes, bread, and gruel in various proportions, and with various systems of alternation.

The surgeon has power to add to the dietary if he should see fit; and such additions are commonly bread or milk. Bread and water are rarely given as an ordinary dietary*, except for "prison offences;" and for these the prisoners may be condemned to the dark cell and bread-and-water dietary for a period not exceeding three days at one time. If the prisoners have been condemned to hard labour, this most severe punishment may be extended to one month; but after three days he is fed on bread and gruel. Flogging is resorted to in various prisons as a part of the sentence upon prison offences, if the prisoner have been convicted of felony; and a return in reference to it has recently been issued. The gaols in which the largest number of prisoners were flogged for prison offences were those which had the most non-remunerative punishments; and in this respect the gaols at Manchester and Liverpool offer a striking contrast. In military prisons it is understood that the punishments are still more severe, since they are inflicted under the Mutiny Act; and it is very desirable that authorized returns should be obtained from them.

The foregoing general observations may suffice to show that he who attempts to ascertain the effect of the present system of prison punishments and dietary undertakes an inquiry of the widest kind, and, with the diversity

* In the Gloucester Gaol bread and water are still given as a dietary.

of system which exists, he will need to present nearly as many reports as there are gaols to be reported upon.

SCIENTIFIC RESEARCHES.

The Committee now proceed to consider the effect of prison discipline over the bodily functions of the prisoners, and will include in their report the result of the inquiries made by them into the variation of the weight of the prisoners, the excretion of nitrogen and carbon, the quantity of air inspired, and the rate of pulsation and respiration.

Variation in Weight.

The value of weight as an indication of the healthfulness and vigour of the body is one of a very general character only, and, when applied to test the effects of any agent over a number of men relatively to each other, is of little worth until all the men have been brought into nearly the same bodily condition. The weight of the body is due to many circumstauces of very different values, as, for example, to the contained food and excretions, the amount of fluid in the circulation and in the tissues, the deposited fat, and to the size of the bones, quite apart from the nitrogenous elements to which reference is essentially made when an estimation is attempted of the vigour and healthfulness of men. Many of these elements can never be truthfully estimated; but in prison discipline it has been ascertained that some of them are removed during the earlier periods of imprisonment—as, for example, fat and superfluous fluid; and, with the reduction in weight which follows, the body gains a higher relative nitrogenous composition.

When, therefore, the body has been so reduced in weight by the labour and discipline enforced, the condition of the men may be compared with greater truthfulness, and weight will be a fair index of the vigour and healthfulness of the system. Hence, whilst investigations into the influence of prison discipline over the weight of the prisoners must be regarded as of great value, they must give place in importance to such as determine the influence of the discipline over each separate function of the organism.

Much difference of opinion exists in gaols as to the value of the test of weight; and in many it is so lightly esteemed that it is not applied at all. In other gaols it is usual to weigh the prisoners on entrance and discharge; and in a few the weight is taken monthly; but in none is it effected with such rigorous exactitude as to fit the results for the use of the physiologist. It is manifest that the weighings should be made before breakfast, and after emitting the excretions, and also that the prisoner should be weighed naked, or the clothes be weighed apart and the weight of them deducted carefully on each occasion; for otherwise the former will lead to an error of 2 lbs. in either direction, and the latter to an error of a smaller amount, even if the external clothing be the same on each occasion. This, however, is not attended to in any gaol, but the prisoners are weighed at various hours, and a standard weight is allowed for the clothes.

Mr. Milner has investigated this subject during a period of more than ten years, including several thousands of prisoners, and embracing the questions of duration of imprisonment, employment, season, and others of a subordinate importance; and to these the Committee will now refer. Appendix III.

The diet on the convict side at the Wakefield House of Correction is liberal and uniform, consisting of 20 ozs. of bread, 4 ozs. of cooked beef, $\frac{1}{2}$ pint of soup, 1 lb. of potatoes, $\frac{3}{4}$ pint of skimmed milk, and 2 ozs. of oatmeal. The dress is sufficiently warm. The prisoners have running and walking exercise during nine hours per week, and are all employed in some manufacturing occupation, as mat- and matting-making, tailoring, or shoemaking. There are not now any of the proper prison punishments, as the crank and the treadwheel, used at that gaol. The cells offer a capacity of 900 cubic feet, and 35 cubic feet of air per minute for each prisoner, with a mean monthly temperature varying from 56°·9 in March, to 66°·5 in August. The average age of the 4000 prisoners under inquiry was 26½ years, of whom 25 per cent. were under 21 years, and were therefore still at the period of growth.

In reference to duration of imprisonment, Mr. Milner states as follows:—

"*Duration of Imprisonment.*—I have divided the time of imprisonment at Wakefield into periods of two months each, and have tabulated six of these periods, so as to show the variation of the weight of the men during the first twelve months of their stay. (Appendix IV.) I have not carried the table any further, as very few prisoners remained longer than twelve months, and those that were detained beyond that time were chiefly invalids, and, consequently, cases from which no general inferences could be fairly drawn.

"The table shows the gains and losses in bi-monthly periods, and also the proportion of prisoners who had to be placed on the extra diet list, who were first placed on the list during each period. The number placed on extra diet during the first twelve months of their stay, was 1393, out of which number 3·14 per cent. were put on during the first two months, and 12·31 per cent. during the second two months.

"The stage of their imprisonment had evidently a very marked effect. During the first two months the majority gained weight; in the second bi-monthly period a large loss occurred, equal to nearly twice the amount gained in the first period; in the third period there was still a loss, but not to so great an amount; the next three periods show a steadily increasing gain.

"For a due understanding of these fluctuations, it is necessary to consider the circumstances under which prisoners are received into this prison. They are all brought from other prisons after having been tried and sentenced to various periods of transportation, or penal servitude; they have consequently passed through the period of anxiety which elapses between committal and trial, during which time, I have reason to think, men often fall off very much in condition and health. When we receive them their fate is decided, and they know the worst. In a large proportion of cases, I believe this is followed by a feeling of relief and by a reaction of the mind against the depression under which it had previously been suffering; later on, the continued imprisonment begins to tell and it becomes necessary to give extra diet to counteract its depressing tendency. A reference to the tables shows that it was thought necessary to give extra diet to a large number of prisoners during the fifth, sixth, seventh, and eighth months. The number of prisoners who were placed on the extra diet list for the first time during these four months, was nearly twenty-one per cent. of the prisoners in confinement, and 60 per cent. of the whole number who were put on extra diet during the twelvemonths.

"The effect of this addition to the diet is shown by the gradual and progressive improvement during the last three bi-monthly periods, when the amount gained, added to the gain of the first period, nearly restored the equilibrium of the mass.

"*Prison Employment.*—In Appendix V. the employments of the prisoners are distributed into five groups, putting into each group the classes of workmen who, as a class, were most nearly associated in the average amount gained or lost during their stay; and when arranged on this principle, it will be found that the groups also represent very accurately the amount of muscular force required to be expended in the respective kinds of work at which they were employed.

"The *first group* consists of men employed in picking oakum, an occupation in which the labour is merely nominal; and it will be seen that these men gained nearly two pounds each on the average, and that a large percentage of them were gaining weight. The oakum-pickers are placed in a group by themselves, as they consist principally of exceptional cases, a large proportion of them being men who, from weakness or infirmity, were unfit for real labour; many were, on medical grounds, employed in the garden, and had extra allowances. The *second group* contains men working at sedentary trades, as tailors and shoemakers, as well as a few employed in writing and other light occupations. Of these men a large per-centage gained weight, and the average gain was nearly a pound and three quarters per man. The *third group* comprises carpenters, mechanics, and men employed in winding the yarn into balls, or winding it on to bobbins for the mat-makers. The men in this group generally work standing, and therefore a greater number of muscles have to be brought into play. The weight of work, however, is thrown on the arms, and the legs have little more to do than to support the body in a convenient attitude. A smaller per-centage of these gained weight, and the average amount gained was less. The *fourth group* contains the men employed in weaving canvas, in making mats in the loom or on boards, and also a small number (thirty-six) who were engaged in platting coir, or in binding mats. The work of all these men is decidedly heavier than that of the men forming the preceding groups, and the *majority of these were found to have lost weight.* The *last group* contains only one class of work, viz. the weaving of coir matting; but the effects of this were so very decided that it was necessary to give it a place to itself.

"The weaving of coir matting by hand is a very laborious occupation: the yarn is coarse and rough, so that the friction between the thread of the warp and weft is great, and to produce good firm work the weft has to be heavily and repeatedly struck, in doing which the muscles of the arms and trunk are brought into powerful action; the legs have also to be employed in working the treddles, and, in consequence of the power required to work the loom, the weaver cannot work sitting.

"The effect of this greater expenditure of muscular force is very manifest; for nearly 80 per cent. of the men so employed lost weight during their stay, and the average loss per man was nearly seven pounds.

"The influence of the various employments would have been much more marked if it had not been, in some degree, counteracted by the extra diet given to those men who were falling off very much in weight; and the numbers to whom it was found necessary to give extra diet, in each class, also bore a pretty close relation to the amount of muscular force expended. Among the men employed in coir-picking, 26·8 per cent. had to be placed on extra diet; in the second group 26·4 per cent.; in the third 36·8 per cent.; in the fourth group 39·4 per cent.; while of the matting-weavers 60·1 per cent. required additional food.

"*Treadwheel Labour.*—The Committee have not been immediately associated with inquiries into the influence of the proper prison punishments over the weight of the prisoners, such as the treadwheel, crank, and shot-drill; but their inquiries warrant them in stating that the normal action of these punishments is to reduce the weight of the prisoners. In the absence of the

'Return' above referred to, it will not be possible for the Committee to discuss this influence satisfactorily.

"The only returns in reference to treadwheel labour which have been obtained are given in the Appendix (VI.), and have been kindly furnished by the governor of the Wakefield House of Correction; but they comprehend only a small number of prisoners, for the use of that instrument was discontinued in consequence of the serious loss of weight which it occasioned.

"The average loss of weight was 2·63 lbs. per man during the first week's labour, 4·57 lbs. at the end of the second week, 6 lbs. at the end of the third week, and 7·7 lbs. at the end of the fourth week. The progressive declension in weight with duration of labour is very striking; but it must not be presumed that it would be continued indefinitely, since a point must be at length reached when the weight would be so reduced that it will remain nearly stationary; and the time required to arrive at that point will vary with the fulness of the body, the tone of the tissues, the nature of the dietary, and the severity of the labour. The greatest loss of weight always occurs in the earlier weeks of imprisonment.

"*Age, Weight, and Season.*—On the subordinate questions of age, weight, and the season of the year, Mr. Milner found that those prisoners who were at the period of growth did not grow according to the scale observed in others more favourably circumstanced, but lost weight in an increasing ratio; so that, conversely, he found that the decrease in the virtual loss of weight occurred as the age increased. The prisoners gained weight from March or April to August or September, and lost in the winter months. The loss of weight of the prisoners varied as the height; so that the taller men required an increased quantity of extra food. Appendix VII., VIII., and IX.

"*Summary.*—On summing up the whole question it was found that, with the arrangements of that prison, which were more favourable than the average of prisons both in dietary and punishment, there was an average loss on the whole weighings, although 3635 of 4000 men were under forty years of age."

From the foregoing tables and remarks it will appear that the weight of prisoners is much below that of persons of the same age and height in a state of freedom, and also that loss of weight during imprisonment is the normal condition of prison discipline.

This result doubtless depends partly upon the relation of food and exertion, and partly upon the inability of the system to assimilate the ordinary food of mankind with a rapidity sufficient to meet the wants induced by constant and great labour. The Committee do not purpose on the present occasion to consider the question of the exact amount of food required to meet the wants of the prisoners; but as in the foregoing remarks reference has been frequently made to the necessity of giving extra diet in order to avert loss of weight, it is deemed right to introduce two interesting facts which came under Mr. Milner's observation.

Effect of Milk.—The effect of milk in arresting loss of weight was most striking, and in a degree far beyond that of the relation of its nutritive elements to the waste of the system. Thus the addition upon his recommendation of only $\frac{1}{4}$ pint of skimmed milk, containing not more than 7 grs. of nitrogen, to the daily dietary, was followed by a reduction in the extra diets from 22·55 per cent. in 1853 to 15·08 per cent. in the first nine months after the additions in 1854, 15·27 in 1855, 14·08 per cent. in 1856, to 9·56 per cent. in 1857. As the extra diets represent the cases permanently losing weight, it is manifest that milk was the proper remedy to meet the loss, and that it acted not simply by supplying a small quantity of nitrogen to obviate the waste of the nitrogenous tissues, but in an indirect manner by improving the general nutrition of the system in the matter pointed out by Dr. Smith in the 'Phil. Trans.' of 1859.

Effect of Tea.—The effect of tea in lessening weight was also largely investigated by Mr. Milner in 1857, both as an addition to the ordinary dietary, and in substitution of the oatmeal contained in the gruel.

Four divisions of the prison, each containing between forty and fifty prisoners, were chosen for observation and comparison.

The divisions chosen were Nos. 2 and 3 in B and C wings.

The prisoners in the division No. 2 were chiefly employed in mat-weaving, and those in division No. 3 in mat-making.

The prisoners in the 2nd division of B wing had a pint of tea given to them *in addition to* the regular diet of the prison. The prisoners in the 3rd division of B wing had a pint of tea given to them *in place of* the pint of gruel served out for supper; the prisoners in the 2nd and 3rd divisions of C wing remained on the regular diet. All the prisoners in these four divisions were weighed every week during the continuance of the observations. At the end of the period the result was thus:—

	lb.
The prisoners in the 2nd division of B wing had gained on the average	0·31
The prisoners in the 2nd division of C wing had on the average gained	0·44
Showing a virtual loss by the prisoners who had had tea in addition to the regular diet, of	0·13
The prisoners in the 3rd division of B wing had gained on the average	0·04
The prisoners in the 3rd division of C wing had gained on the average	0·20
Showing a virtual loss by the prisoners who had had tea in place of gruel, of	0·14

Thus, so far as the results obtained from one set of prisoners may be compared with those obtained from other sets, it must be admitted that these experiments prove that the use of tea tended to lessen the weight of the prisoners, and consequently to show that it is unsuited as an article for extra diets.

Respiration and Pulsation.

The Committee now proceed to give the details of their inquiries into the influence of the agents under consideration over some of the vital processes of the body, and first those of the respiration and pulsation. The inquiries comprehend experiments as to the quantity of air inspired and of carbonic acid expired, and the rate of the functions of respiration and pulsation. In reference to the value of the quantity of respired air as a measure of vital action, the Committee refer to the inquiries previously made by Dr. Smith and published in the 'Philosophical Transactions' for 1859, which have shown that, whilst there is not an unvarying relation between the air inspired and the carbonic acid expired in ordinary respiration, but that the ratio increases with the severity of the exertion, there is such a correspondence that the one may be used as a measure of the other in ordinary inquiries, and especially that the measure of the air inspired may be used as a measure of the relative effects of similar agents.

The effects of the most laborious prison occupations, as the treadwheel, crank, and shot drill, over the respiratory function and over pulsation have been determined by Dr. Smith, by experiments made upon himself in Coldbath-fields, Wandsworth, the New Bailey Salford, and Canterbury prisons. The experiments upon the quantity of air inspired were made by the aid of a spirometer, which was a dry gas-meter with an inverted action and enlarged apertures, and was connected with the body by a mask which enclosed the nose, mouth and chin, and prevented ingress and egress of air, except through pre-arranged valvular openings. This was bound upon the head with straps. The spirometer was adapted to register from 1 to one million cubic inches. The inquiry in reference to the carbonic acid was made by the aid of a double set of the apparatus elsewhere described*.

With Treadwheel Labour.—The effect of treadwheel labour varies in different prisons with the rapidity of the ascent, and other phenomena. Thus at the Coldbath-fields prison the amount of air inspired per minute during two minutes after having been upon the wheel five minutes, and again during two minutes after having been upon the wheel thirteen minutes, was, in various experiments, from five to six times the quantity expired at rest, viz. 2900, 2605, 2350, 2350, 2435, 2460, and 2450 cubic inches, giving an average of 2500 cubic inches per minute.

At the New Bailey, Salford, the average of experiments made upon two days gave only between three and four times the quantity at rest, viz., 1839 cubic inches per minute.

At the Canterbury gaol the amount was even less, and varied from 1607 to 1820 cubic inches per minute; but as the rate of ascent varied greatly at that treadwheel, it was impossible to obtain fair average results.

The rate of respiration at Coldbath-fields was about double that at rest, viz., 27, 26½, 25, 23½, 24½, 25, and 26 per minute. At the New Bailey it was 24 per minute; at Canterbury it was still less, and varied from 21½ to 24 per minute. The depth of inspiration at Coldbath-fields was from 3 to 4 times that at rest, viz., 107½, 91½, 94, 100, 99⅓, 98½, and 94¼ cubic inches. The rate of pulsation at Coldbath-fields was more than double of that at rest, viz., 150, 172, and 168 per minute; at the New Bailey 159, and at Canterbury 140 to 158 per minute. That of the prisoners was at the New Bailey from 125 to 155 per minute; and at Canterbury, from 118 to 142 per minute.

Such was the effect of the labour during the period of exertion; but in order to determine the full influence it is necessary to refer to the intervening periods of rest also; and in doing so it will be found that, during the whole period of rest allowed, the functions were never restored to their normal action.

At Coldbath-fields, after thirteen minutes' rest, the quantity of air inspired was still nearly double of that at rest, viz., 980 and 815 cubic inches per minute; and at the New Bailey, after four minutes' rest, it was 855 cubic inches. The rate of respiration at Coldbath-fields was reduced to an addition of about ¼, viz., 18½, 15, and 16½ per minute, and at the New Bailey to 18 per minute.

The depth of respiration was nearly one-half greater than during normal rest, viz., 53, 48, and 49 cubic inches at Coldbath-fields.

The rate of pulsation at Coldbath-fields was one half more than the normal amount, 110, 97, and 120 per minute, whilst at the New Bailey it was reduced to 109 per minute.

These two sets of inquiries, when conjoined with the knowledge of the prescribed duration of each, enables us to compare the effect of these modes of punishment at the different gaols, notwithstanding the almost un-

* 'Health and Disease as influenced by the Daily Seasonal and other Cyclical Changes in the Human System.' By Edward Smith, M.D., F.R.S. Walton and Maberly.

accountable diversity which exists in the use of them; and the result will show, in a most striking manner, the great accuracy with which experience enables ordinary officials to regulate their system of punishment to the full powers of endurance of the prisoners.

It is customary at Coldbath-fields for the prisoners to work and rest during fifteen minutes alternately; but at the New Bailey they are placed upon the wheel during twelve minutes, and have only four minutes' rest before the labour is renewed. Hence, the actual period of labour at Coldbath-fields is only $3\frac{3}{4}$ hours, but at the New Bailey it is six hours daily; and although the labour is lighter at the New Bailey than at Coldbath-fields the total effect per day is the same in both prisons, as the following estimate proves:—

COLDBATH-FIELDS.

	Total daily. Cubic Inches.
$3\frac{3}{4}$ hours' work with 2500 cubic inches of air inspired per minute	562,500
$3\frac{3}{4}$ „ rest with 1000 „ „ „	225,000
	787,500

NEW BAILEY.

6 hours' work with 1850 cubic inches of air inspired per minute..	666,000
2 „ rest with 950 „ „ „	114,000
	780,000

Thus, with the use of instruments differing so greatly in power over the human system, the plan pursued in each gaol is so well adapted to the usual powers of the body, that the difference in the effect is only equal to about three minutes' actual labour upon the treadwheel at Coldbath-fields, and four minutes' at that at the New Bailey. This result illustrates also the accuracy of the method of inquiry thus adopted.

The influence of this kind of labour over the production of carbonic acid as well as over the rate of the functions, was established by another set of experiments made in a similar manner at Coldbath-fields prison.

The apparatus employed was that already mentioned, and was used without inconvenience when placed upon a shelf over the wheel and at a suitable distance from the person to be experimented upon. As there was necessarily some adverse weight placed upon the expiration by the collection of the carbonic acid, it was not thought advisable to measure the air inspired also, lest the result should be vitiated by placing some impediment upon both acts of respiration at a time when the deepest and most frequent inspirations were demanded; and hence that part of the inquiry was abandoned. The ascent of the body upon the wheel was 28·65 feet per minute, and the weight to be lifted was 200 lbs., and hence the labour actually performed was equal to lifting 575·558 tons through 1 foot per day. The duration of the labour was a quarter of an hour at a time, and the carbonic acid was collected during three minutes after having been upon the wheel five minutes, and during two minutes after ten or after thirteen minutes. Thus the carbonic acid was collected during five of each fifteen minutes. The quantity obtained per minute was between five and six times that expired in normal rest, viz., 43·36 grains, 42·9 grains, and 48·66 grains on different days, the latter quantity having been found soon after a good prison-dinner of soup. The average excretion of carbonic acid under the influence of treadwheel-labour was thus 45 grains per minute.

The rate of respiration was 22, 21, and 20, and that of pulsation 150 per minute on each of the occasions referred to.

The carbonic acid was also collected in the interval which followed the labour, viz., during three minutes after four minutes' rest, two minutes after ten minutes' rest, and two minutes after thirteen minutes' rest; and, on the average of the whole, the rate of excretion was above that at rest, viz., 9·14 grains per minute. The quantity of air inspired was also measured at the same periods, and was somewhat less than that which occurred in the previous experiments, viz., 680, 590 and 600 cubic inches, 560 and 540 cubic inches, and 560 and 570 cubic inches per minute. The rate of respiration was 17, 16 and 15, and the rate of pulsation at the end of the 15 minutes' rest, was 102 per minute.

Thus the results obtained from inquiries into the quantity of air inspired and of carbonic acid expired during treadwheel-labour closely correspond, and show that at Coldbath-fields the influence of that mode of punishment is to increase the elimination of respiratory products from five to six times during the period of actual labour.

With the Hard-labour Crank.—The next series of experiments refer to the influence of the crank as an instrument of punishment. This instrument is simply a hand-mill which demands a certain expenditure of force to move the handle, and is described as having a pressure of such a number of pounds as may be requisite to depress the handle from the horizontal to the vertical position. It is not used profitably, and is worked by each prisoner separately in his cell. Experiments have been made at Wandsworth and the New Bailey prisons in the manner already described.

At Wandsworth the cranks are Appold's patent, and are of superior construction. They move with a minimum pressure of 7 lbs., but the pressure required to move them may be increased to 10 or 12 lbs. by a prepared set of weights. The usual number of revolutions which the prisoner must make per day of ten hours, is 13,500; but that number may be reduced at the discretion of the Surgeon. The index is in sight of the prisoner, so that he may ascertain the progress of his work.

The experiments were made at several periods on two days with 7 lbs. and 12 lbs. pressure, and with varying rates of speed. The rate which was the most natural was forty revolutions per minute, but the prisoners generally performed about thirty per minute. The effect upon the system varied much, both with the pressure and the speed; but, excepting the rate of pulsation, the very interesting fact was educed, that *the total effect of the day's work in performing the required number of revolutions was nearly the same, whether the rate was 30 or 45 per minute. With 7 lbs. pressure* and 30 revolutions per minute, the quantity of air inspired was somewhat less than double of that at rest, viz., 912½ cubic inches per minute, with 17 respirations and 92 pulsations per minute. With the speed increased to 45·7 revolutions per minute, the quantities of air inspired were increased to nearly three times that at rest, viz., 1336 cubic inches, with 21·5 respirations and 113 pulsations per minute.

With 12 lbs. pressure and 30 revolutions per minute, the quantity of air inspired was between 2 and 3 times that at rest, viz., 1260 cubic inches; the rate of respiration 24·7, and the rate of pulsation 111·5, per minute. Two experiments gave almost identically the same results, the only difference being 3 pulsations, ·4 respiration, and 3 cubic inches of air per minute. With the speed increased to 44·7 revolutions per minute, the average of two experiments gave 1898 cubic inches of air, or about 4 times that at rest, with 24·7 respirations and 150 pulsations per minute.

The effect of speed in reference to the day's work of 13,500 revolutions may be thus shown:—

1. With a pressure of 7 lbs. With 30 revolutions per minute 7 hours $33\frac{1}{3}$ minutes will be employed in completing the task, and the total quantity of air inspired will be 415,636 cubic inches; but if the rate be 45·7 revolutions per minute, the task may be completed in 4 hours 55·4 minutes, and the total quantity of air inspired will be 345,654 cubic inches, giving a difference of 7982 cubic inches, or only 6 minutes' labour at the greater speed in favour of the increased speed.

2. With a pressure of 12 lbs. With 30 revolutions per minute the total quantity of air inspired will be 571,158 cubic inches, and with 44·7 revolutions per minute it will be 573,196 cubic inches per minute, quantities which for all purposes may be regarded as identical.

Hence the law is established that the effect upon the system of the whole day's work varies little with the speed, provided there be a fixed number of revolutions per day.

The experiments in reference to the effect of the two pressures with the same kind of crank, show that with the ordinary rate of revolution the influence of the 7 lbs. to the 12 lbs. is a little more than as 3 to 5, or in general terms it may be affirmed that $3\frac{1}{4}$ hours' labour with the 12 lbs. pressure is equal to 5 hours with 7 lbs. pressure. When the rate was increased beyond the ordinary one, the relative effect of the greater pressure was somewhat higher.

The cranks used at the New Bailey prison are much inferior to those found at Wandsworth, and the pressure employed cannot be rigorously determined. The medium amount of pressure was estimated at 7 lbs.; and the effect of this labour with a rate of revolution of 36·5, 39·5, and 40 per minute was to cause the inspiration of nearly double of that of the 7 lbs. crank at Wandsworth, viz., 1793 cubic inches of air per minute, with $21\frac{1}{2}$ respirations and 155 pulsations per minute. When the pressure was increased to the one of nominally 9 lbs., the quantities were nearly 75 per cent. higher than that of the 12 lbs. crank at Wandsworth, viz., 2105 cubic inches of air, with $23\frac{1}{2}$ respirations per minute. Hence the effect was much greater at this than at the Wandsworth prison, and the pressure, although nominally the same, was fearfully different.

Such is the effect of crank-labour, an effect which time for time is less than that of the treadwheel; but the experience in prisons proves that crank-labour is not inferior in severity to that of the treadwheel, and, in the observation of many, has long been believed to exceed it. The inquiries now recorded enable us to determine this question with exactitude, and to show that, when the duration of the labour is taken into consideration, the effect of the crank at the New Bailey is so great that the treadwheel may be used as a relief from it.

In comparing the effect of crank- and treadwheel-labour, it has been shown that the 12 lbs. crank at Wandsworth and the so-called 7 lbs. crank at the New Bailey, are equal time for time to that of the treadwheel at the New Bailey, but that the effect of the so-called 9 lbs. crank at the New Bailey is nearly equal to that of the treadwheel at Coldbath-fields, when considered time for time; but as the time of actual daily labour with the crank is double that of the actual labour on the treadwheel, the whole daily effect must be so striking as double of that of the treadwheel. Can it be wondered at that the punishment of the lash and of the dark cell for neglect of work is frequent at the New Bailey, and in general in all prisons where the ordinary punishments are very severe?

With the Shot-drill.—This punishment is common in military prisons, but in civil prisons it is used unfrequently and rather as an exercise and an alleviation from more severe labour. The labour varies with the weight of the shot to be carried, the weight of the body, and the rate of speed. The weight of the shot is known and regulated, but varies in different prisons, whilst the speed is dependent upon the will of the presiding officer. With a 16 lbs. shot at Coldbath-fields, the average of three inquiries showed that the quantity of air inspired amounted to nearly 4 times the amount at rest, viz., 1800 cubic inches per minute; and the rate of pulsation was 146 per minute; but with the 24 lbs. shot the quantities increased to 1850 cubic inches, and 154 pulsations per minute. The increase in the quantity of air inspired corresponded with that observed by Dr. Smith when carrying various weights at the "quick march," viz., an increase of 7 cubic inches for each lb. of weight. The 32 lbs. shot is commonly employed in military prisons, but no experiments have been made with it. The chief sense of suffering in this labour is found in the arms and back, from the frequent stooping and lifting which are required, and therefore it is evident that persons of different height and bulk will be influenced variously.

Emission of Nitrogen.

The next series of inquiries to which reference will be made, are those which show the influence of prison discipline over the excretion of nitrogen, and which constitute the most laborious and extended portion of these researches. They consist of two sets, one of which was prosecuted at Coldbath-fields under the immediate supervision of Dr. Smith, and the other at Wakefield under that of Mr. Milner. The same series were also employed to determine the relation of the ingested and egested nitrogen; but this part of the inquiry will, as has been already mentioned, be reserved for the second part of this report.

Experiments at Coldbath-fields Prison*.

In the first set of inquiries four prisoners in Coldbath-fields prison were selected who had been some time in prison, and who worked the treadwheel on three days in each week. Their ages varied from 22 to 43 years, their height from 5 feet $2\frac{1}{4}$ inches to 5 feet 7 inches, and their weight from 105·1 lbs. to 122·6 lbs., and the averages were 32 years, 5 feet $4\frac{1}{4}$ inches, and 113·75 lbs. They were spare but in good health, and their habits of body were tolerably regular. By the kindness of the Visiting Justices and the governor of the prison, Mr. Lambert, the third officer, took these men under his immediate charge, and collected the urine, weighed the fæces, weighed the food and the body, superintended the meals, the period of exertion, and the whole general arrangements of the inquiry. The inquiry occupied 26 days. The dietary was uniform, with the exceptions to be presently mentioned, and consisted of 20 ozs. of brown bread, 1 pint of cocoa, 1 pint of gruel, $4\frac{1}{2}$ ozs. of lean and $1\frac{1}{2}$ oz. of fat cooked meat, 8 ozs. of boiled potatoes, 1 oz. (reduced to $\frac{3}{4}$ oz.) of salt, and 30 ozs. of water; and one of the men had $6\frac{2}{3}$ ozs. of extra bread per day. The average quantity of solid food was 34 oz., and of fluid 70 ozs., daily, besides the ingredients of the gruel and cocoa, and the extra bread of one of the prisoners. The exceptions made in the dietary were as follows:—No salt, except that in the cooked food, was allowed during four days; and $3\frac{1}{2}$ ozs. of extra fat, $\frac{1}{2}$ oz. of tea, $1\frac{1}{2}$ oz. of coffee, and 2 ozs. of alcohol, were separately given through succeeding periods of three days each.

* For further details than are included in this Report, see 'Philosophical Transactions,' 1861.

The discipline enforced consisted of treadwheel-labour on three days weekly, from $7\frac{1}{4}$ A.M. to $5\frac{1}{3}$ P.M., comprehending a period of $3\frac{1}{2}$ hours of actual labour, and an actual ascent of 1·432 mile, and was equal to lifting 384 tons through 1 foot daily. On the alternate days the labour was oakum-picking, or similar light occupation, and on Sunday there was perfect rest.

The urine was collected in bottles which were used also whilst passing fæces. Two collections only were made on Sundays, viz., those of the day and night, but on the weekdays the urine was also collected separately, from 6.15 to 7.15 A.M.; and on the treadwheel-days from 7.15 to 8.25, A.M. These two latter sets of quantities were termed "basal quantities," since by one it was hoped to determine the actual rate of urinary excretion in the absence of food, and by the other the influence of treadwheel labour apart from any other influence. The analyses for urea and chloride of sodium were made by Dr. Smith; but those of the food and fæces, and the final analyses of the urine were kindly made by Mr. Manning. The samples for analysis were taken with the utmost care. The details of this investigation are very numerous; and probably it may suffice to give the following principal results of the inquiry.

Urea.—The proportion of urea to each lb. of body-weight, both on days of labour and on those of rest, was much above that found in the ordinary conditions of life, viz., from 4·39 grains to 4·74 grains, or an average of 4·58 grains to each lb. of body-weight. It was less than 4 grains to each lb. on only one occasion in each of the lighter, and on three occasions in each of the two heavier men, whilst Dr. Smith found in himself with about the same food, but with much greater weight of body, an average proportion of only 2·75 grains to each lb. The cause as well as the significance of this fact is not clear; for, as it occurs with rest as well as labour, it can scarcely be an evidence of increased degradation of tissue, and as the food allowed is not much beyond that which a man in health would ordinarily eat, it cannot be the result of an undue ingestion of nitrogenous food. The probable explanation is that already referred to, viz., that the nitrogenous tissues in the bodies of prisoners after a certain term of imprisonment, bear a larger proportion to the weight of the whole body than is found in health under ordinary conditions, since, by the labour and discipline of the jail, they have lost much of their fat and the fluid contained in the tissues is reduced to a minimum quantity. The average weight of these men was much below the ordinary weight of men of their age and height. If this be the true explanation, the relation of urea to body-weight loses much of its physiological importance.

The urea excreted during treadwheel-labour before breakfast showed that such exertion had no definite influence over the elimination of that product. In one of the cases the excretion of urea was much greater than in the others. There was some diversity in the quantities evolved by the others; so that in one they were the same in labour as at rest, in another there was an excess of 2·5 grains per hour with rest, and in the 3rd there was an increase of 1·9 grain per hour with labour; but on the average, of all the three over the whole period, there was ·2 grain per hour less evolved with labour than during rest; and on the average of all the four prisoners, this defect was so much as 2·4 grains per hour. There were numerous occasions on which there was an excess with labour, viz. 28, 33, and 71 per cent. of the observation in the three cases above separated. The greatest excess with labour was 7·5 grains, and the greatest defect with labour was 5·3 grains per hour, and both occurred in the same person.

As this inquiry occupied only 80 minutes at one time, it is very probable that the urea produced would not be eliminated within that period, and hence we cannot take this as indisputable evidence of the effect of treadwheel-labour. The variations above referred to were also, in part at least, due to the variation in the quantity of urinary water which was secreted during that period; and it is just possible that, notwithstanding every care, the bladder might not have been completely emptied on each occasion.

The total daily excretion of urea was the least on the Sunday, greater on the days of light labour, and the greatest on days of treadwheel-labour, on which occasions the average quantities were 494, 512, and 528 grains, giving a daily increase on treadwheel-days of 16 grains over that of days of light labour, and of 34 grains over that of perfect rest. There were some diversities in the results, owing, apparently, to the fact that on two occasions the elimination of the urea due to the treadwheel-days was in part deferred until the next day, when there were remarkable meteorological disturbances, and thus gave the appearance of greater elimination on the days of light or of no labour. From this cause one of the cases gave an average decrease of 51 grains of urea on the days of treadwheel-labour, but in the other three prisoners the increase with labour was 37, 59, and 21 grains daily. The largest increase on the treadwheel-days was 144 grains, and the largest decrease 100 grains per day.

Urinary Water.—The quantity of urinary water evolved was, on the total average, 10·4 per cent. greater on treadwheel than on other days, viz., 74·7 and 67·7 fl. ozs., and the same relation held good in each of the cases. Thus

Register No. of Prisoner.	On Treadwheel days. ozs.	On other days. ozs.
858	79·4	73·15
948	82·87	70·8
1040	67·9	63·8
1041	68·9	62·9

The quantity of fluid drank was the same on each day, and the amount lost by perspiration was much greater on treadwheel-days than on other days; and hence the blood and tissues must have lost considerably more fluid with great labour than occurs with rest.

Chloride of Sodium.—The evolution of chloride of sodium was very great, owing to the large quantity taken with food, but was somewhat less on treadwheel days than on other days, viz., 509 and 520 grains. When the quantity of chloride of sodium taken with the food was diminished, the same relation was still maintained, but in a less degree, viz., 432 and 437 grains. There was much variation in the results.

Hence, from all these inquiries, it follows that there is an increased elimination of urea and urinary water with treadwheel-labour, but the former is much less and the latter much more than we should have expected. Neither of them are efficient measures of the true effect of exertion.

Fæces.—The determination of the daily evacuation of fæces was rendered difficult from the habit of one of the prisoners to have an evacuation only on alternate days, and the only method by which we could make an approximation to the daily evacuation was to divide the quantity on alternate days into two equal parts, and reckon one part on the day on which no evacuation occurred. The fæces were also placed under the date of the preceding day, as they clearly were due to the conditions of that day. The following are the principal facts educed:—

1. The average weight of the fæces daily was double of that found in

ordinary life, and varied on the average of the different prisoners, from 7·1 to 10·1 ozs., and gave so large a total average as 8·55 ozs. The extremes of single observations were 1·75 and 26·59 ozs. The proportion to the solid food was $22\frac{1}{2}$ per cent.

2. The weight was increased on Sunday by 44·3, 70, and 74 per cent. of that on all days.

3. The weight was lessened on the treadwheel-days from that observed on Sundays, by 41, 53·3, and 42·6 per cent. in three cases, and from the average of all days by 14·8 and 21·1 in two cases, whilst in the 3rd case the weight was equal on all days.

4. The least evacuation occurred on the Saturday (which was also a treadwheel-day), and the diminution from the weight of all days was 26·1, 57·6, and 34·6 per cent., and from that on Sundays no less than 48, 75, and 62 per cent.

5. The proportion of water contained in the fæces was very uniform from day to day, viz., 73·5 per cent., and varied only from 71·8 to 77·6 per cent. on different days. It was above the average on Sundays and a little below the average on treadwheel-days.

6. The quantity of nitrogen in each oz. of fresh fæces varied from 4·36 to 4·9 grains, and was, on the average, 4·646 grains. The total daily quantity thus evacuated, was, on the average, no less than 41·8 grains. There was a considerable increase on the Sunday, and a marked decrease on the Saturday, and it was below the average on treadwheel-days, and in both of these respects it corresponded with the gross weight of the fæces. The actual amounts under the three conditions were 59·9, 35·8, and 40·53 grains, giving an increase of 43·3 per cent. and a decrease of 14·3 and 3 per cent. There was a very interesting fact noticed in reference to the relation of nitrogen in the urine and fæces on the Sunday, and which showed, probably, that the assimilation of food was lessened on a day of perfect rest following one of hard labour, viz., that the increase which was observed in the nitrogen in the fæces on the Sunday corresponded accurately with the decrease observed in the urine on that day, viz., a decrease of 13 and 18 grains of urea in the urine, and an increase of nitrogen, reckoned as urea, in the fæces, of 71·33 grains.

7. The case which had the extra allowance of $6\frac{2}{3}$ ozs. of bread daily, evacuated the largest amount of fæces, both on the total average and on Sundays,—a fact of great significance in reference to the kind of food which should be selected for extra diets.

Summary.—Thus, on reconsidering the foregoing results obtained from this large series of inquiries, the following general facts were elicited:—

The prisoners emitted much more urea and fæces than occurs in ordinary life.

On Sundays, with entire rest, the amount of urea was commonly lessened, but the nitrogen in the fæces was increased in the same degree. The whole weight of the fæces was increased.

With treadwheel-labour there was a small increase in the amount of urea and of urine evolved, whilst there was a small decrease in the evolution of chloride of sodium in the urine, in the weight of the fæces, and the nitrogen and the fluid contained in the fæces.

On Saturdays, with treadwheel-labour, the diminution in the weight and nitrogenous matter of the fæces was considerable.

With increase in the allowance of bread to a prisoner who was believed to need extra diet, there was a considerable increase in the weight of the fæces and loss of their nitrogen, and particularly with rest.

Experiments with Fat, Tea, Coffee, and Alcohol.—The foregoing observations will be again referred to at the end of the report, and will form a basis upon which the Committee may offer some recommendations; and before closing the analysis of this inquiry the Committee propose to state the results of certain short experiments which were made upon the effect of fat, tea, coffee, and alcohol when temporarily added to the dietary. It is not proposed on this occasion to enter into detail, since the results obtained point to the desirability of conducting similar inquiries through much longer periods.

The issue of the inquiries was as follows:—

1. During the period of the administration of $3\frac{1}{2}$ ozs. of extra fat daily, the amounts of urea and urinary water excreted were 529 grains, and 69·17 ozs. on the average of all the cases, showing that no noticeable change had been produced.

2. During the withdrawal of $\frac{3}{4}$ of an ounce (328 grains) of chloride of sodium daily, the quantity of that salt excreted by the urine was reduced from 506 to 184 grains daily, the difference being almost exactly the amount which had been withheld. After the full supply was renewed, it was some days before the whole again appeared in the urine.

3. The excretion of urea was lessened during the administration of the tea to 402 grains on the second, and 508 grains on the third, which was a treadwheel-day. The exact amount of the diminution cannot be determined, since in the three preceding days two treadwheel-days were included, and thus this basis of comparison was unduly elevated.

The excretion of chloride of sodium was increased to 542 grains per day.

The quantity of urinary water evolved remained unchanged.

4. The urea, which had fallen during the action of tea, remained below the average during the action of coffee (which was administered after the experiments on tea), but it rose 42 grains daily, and at the end of the period was scarcely below the quantity normally evolved. The quantity of chloride of sodium evolved was 50 grains daily less than with the tea, viz., 494 grains.

The quantity of urinary water was not changed.

5. The urea was also lessened during the action of alcohol, to the extent of 26 grains per day below the normal quantity; but it was still 14 grains per day higher than the quantity to which it first fell with the tea. The effect was much more evident with treadwheel-labour on the first day; for, instead of an increase with labour, there was an elimination of 43 grains less than occurred on the previous day with rest, but on the third day the increase with labour was 111 grains over that evolved on the Sunday. On the first day the barometer fell greatly and tended to prevent the elimination of urea. The greatest effect was upon the elimination of urinary water, being a diminution of no less than 20 ounces per day on the average of the three days; and as there was an unusual thirst during the administration of the alcohol (without, however, any additional fluid food being allowed), it is easy to see in how great a degree alcohol tends to temporarily fix fluid in the tissues of the body, and in doing so to restrain the emission of urea. There was also a large diminution in the excretion of chloride of sodium, but it corresponded precisely with the diminution in the urinary water. The quantity evolved daily was 352 grains, or a diminution of 27·5 per cent.

Hence the effect of tea, coffee, and alcohol in lessening the emission of urea appeared to be temporary only, and in the case of alcohol was associated with retention of fluid in the body, and consequently with an increase of weight. The information thus obtained renders it important to test the influence of each article over a much longer period.

Experiments at the Wakefield Prison. Appendix X.

In June 1861 another series of inquiries were prosecuted in Wakefield Goal of a character similar to those just related. Mr. Milner took charge of all the observations which were made within the prison; Dr. Smith made the analyses for urea and chloride of sodium; and Mr. Manning kindly determined the dry matter and the nitrogen in the food, fæces, and urine.

Four men of regular habits and in good state of health were selected. Two were weavers of cocoa matting, which is a very laborious occupation, and two were tailors. Their ages were 19, 22, 24, and 28 years; their height was $64\frac{3}{4}$, 66, $66\frac{3}{4}$, and 67 inches; and their weight was 118 lbs. 11 ozs., 125 lbs. $12\frac{1}{2}$ ozs., 146 lbs. $11\frac{3}{4}$ ozs., and 146 lbs. $15\frac{3}{4}$ ozs. The girth around the nipples was $32\frac{3}{4}$ inches, $34\frac{1}{4}$ in., $35\frac{3}{4}$ in., and $35\frac{1}{4}$ in., giving an average of nearly $34\frac{1}{2}$ inches. The total averages of age, height, weight, and girth were $23\frac{1}{4}$ years, 66·1 inches, 134 lbs. $8\frac{3}{4}$ ozs., and $34\frac{1}{2}$ inches.

They had been fed on the highest class of prison dietary; but as that consisted of some variety of food, it was deemed advisable to give them a uniform daily diet during one week before the experiments began, and it was continued without intermission until the inquiry terminated.

The food supplied daily was in part fixed, and in other part variable in quantity. The fixed quantities were those of meat, oatmeal, and potato, and the variable ones those of bread, salt, and water. Milk was given in a fixed quantity, but the amount supplied was not uniform in both classes of prisoners.

The meat consisted of 5 ozs. of lean and 1 oz. of fat cooked beef, without bone. The supply of oatmeal was 2 ozs., and 16 ozs. of cooked potato; 20 ozs. of skimmed milk were given to the tailors, and 25 ozs. to the weavers. The daily quantity of bread eaten was on the average 30·4 ozs. by the tailors, and 34·3 ozs. by the weavers, or a general total of 27·35 ozs. 136·5 grs. of chloride of sodium were eaten (besides that contained in the bread) by the tailors, and 63·5 grs. by the weavers, giving an average of 100 grs.; but there was some considerable variation from day to day. One of the tailors ate an average quantity of 199·3 grs.; whilst the other tailor ate only 73·8 grs.

The quantity of water which was drunk, besides that contained in 1 pint of gruel, was only 23·8 ozs. on the average, giving with the milk a total supply of fluid of 66·3 ozs. The weavers drank much more than the tailors, and the total daily quantities in the two classes was 80·5 ozs. and 52·1 ozs. The solid food was 51·8 ozs., and the fluid 66·3 ozs., or a total of 118 ounces daily.

The men arose at 6 A.M., and having passed urine and fæces were immediately weighed. The scales employed were good ones, and the weight was taken to $\frac{1}{4}$th of an ounce. The prisoners were weighed naked. The weight of the fæces and urine was ascertained daily, by the aid of balances kindly lent by Messrs. Avery, of Birmingham, up to $6\frac{1}{2}$ A.M.; and the degree of consistence of the fæces was recorded under five heads, viz. scybalous, well-formed, formed but soon subsiding, soft, and liquid. A fair sample of the bread, oatmeal, potato, meat, and milk was sent up to Mr. Manning from time to time as changes in the supply occurred. A portion of the mixed quantities of fæces and the urine of each set of prisoners was most carefully taken and sent for analysis daily; but delay sometimes occurred in the transmission, so that the analyses were usually made on the third day after the evacuation. The greatest care was taken to avoid loss by evaporation and otherwise, and to prevent decomposition. The observations included thirteen days besides the week of preliminary dietary, and the following are the principal results which have been obtained:—

Weight of body.—The average weight of three of the prisoners during the inquiry was greater than that recorded on the day preceding the commencement of the inquiry, but there was a loss of weight in the fourth. The average gain was, in the tailors, $15\frac{1}{2}$ ozs. and $17\frac{3}{4}$ ozs., and in one of the weavers $3\frac{1}{4}$ ozs., but in the other weaver there was a loss of $3\frac{3}{4}$ ozs. The greatest gain in the different cases was 1 lb. $13\frac{1}{4}$ ozs. and 1 lb. $7\frac{1}{2}$ ozs. in the tailors, and $8\frac{3}{4}$ ozs. and 1 lb. 11 ozs. in the weavers; and the greatest loss $1\frac{1}{4}$ oz. in one tailor, 1 lb. $2\frac{1}{4}$ ozs. and $4\frac{1}{2}$ ozs. in the weavers. There was not an unvarying progression in the weight during the week, but in every case there was an increase from the Saturday to the Sunday, and the amounts were as follows:—$11\frac{1}{4}$ ozs. and $10\frac{1}{4}$ ozs., $9\frac{1}{2}$ ozs. and 5 ozs. in the tailors; $6\frac{1}{4}$ ozs. and $18\frac{1}{4}$ ozs., $19\frac{1}{4}$ ozs. and $31\frac{1}{2}$ ozs. in the weavers; or an average increase of 13·62 ozs. on the Sunday.

Urine: quantity.—The largest quantities which were evolved in one day were 25,321 grs. (56·6 ozs.) and 26,624 grs. (59·17 ozs.) in the tailors, and 27,791 grs. (62·3 ozs.) and 32,924 grs. (74 ozs.) in the weavers. The average daily quantity was 41·2 ozs. in the tailors, and 47·51 ozs. in the weavers, giving a total daily average of 44·35 ozs. There was a large increase on the Saturday, and a marked decrease on the Sunday, as the following figures prove:—

	Friday. ozs.	Saturday. ozs.	Sunday. ozs.
Two tailors	—	49·1	39·45
" "	37·85	48·25	37·9
Two weavers	—	51·92	44·98
" "	49·5	57·25	43·

The average decrease from the Saturday to the Sunday was 10·29 ozs.

Specific gravity.—The specific gravity of the urine varied from 1016 to 1027·5, but there was singular uniformity in the general results. In the tailors it was 1023·7 and 1025, and in the weavers 1024·37 and 1024·6, giving a total average of 1024·35 in the tailors, and 1024·45 in the weavers.

Urea.—The analysis for urea was made by Liebig's method, from a test solution which had been prepared in large quantity and used daily in other experiments. The chloride of sodium was not removed, but its amount was duly determined and deducted.

The total average daily quantity of urea evolved was 655·65 grs., of which 608·4 grs. were emitted by the tailors, and 702·9 grs. by the weavers; the maximum and minimum amounts were 790 and 456 grs., the former in the weavers, and the latter in the tailors. In the weavers the quantity exceeded 700 grs. in 7 of 13 days, whilst this occurred only 3 times in the tailors, and in only one instance during the inquiry was it below 500 grs. daily.

The quantity of urea to each pound of body-weight was 4·812 grs. in the tailors, and 4·675 grs. in the weavers; but it varied in the former from 3·72 to 5·82 grs., and in the latter from 3·62 to 5·39 grs. on different days.

The quantity of urea was always lessened on the Sunday. In the tailors the diminution from the Saturday to the Sunday was 145 grs. and 122 grs., and in the weavers 26 and 92 grs., giving a total average diminution of 96·25 grs.

The quantity in each ounce of urine was, on the average, 14·9 grs. in the tailors, and 15·25 grs. in the weavers, giving a total average of 15·075 grs. The maximum and minimum quantities were 18·8 and 12·3 in the tailors, and 17·84 and 13·53 in the weavers.

Chloride of Sodium.—The average quantity of chloride of sodium evolved was 3·37 grs. per oz. in the tailors, and 3·18 grs. per oz. in the weavers, giving a daily emission of 138·844 grs. in the former, and 148·5 grs. in the latter.

Fæces.—The general character of the fæces was homogeneous and moderately cohesive, but on a few occasions there was a variety in the consistence. In the 52 observations 32 exhibited fæces formed but soon subsiding, 7 well formed, 1 scybalous, 2 soft, and 9 of mixed character, and no one person offered any marked difference in these characters. The bran of the brown bread was easily seen in the fæces. The average daily evacuation was 6·98 ozs. in the tailors, and 8·52 ozs. in the weavers, giving a total daily average of 7·75 ozs. There were somewhat considerable daily variations, so that the maximum and minimum quantities were, in the tailors regarded separately, 11·41 ozs. and 4·32 ozs., and in the weavers 14·42 ozs. and 1·72 oz., but in no instance was there the omission of a daily evacuation.

The quantity of nitrogen per cent. found by Mr. Manning by the volumetric method varied from ·71 gr. to 1·16 gr. in the tailors, and from ·97 gr. to 1·35 gr. in the weavers; but the total average in the two classes was ·93 in the tailors, and 1·12 in the weavers, giving 1·025 gr. in the whole.

The total daily elimination of nitrogen by the fæces was found to be 27·43 grs. in the tailors, and 40·93 grs. in the weavers. The variation in the amount of fæces on Sunday from that of other days was not uniform, since it was less in the weavers and was equal in the tailors.

It will have been observed that there were many differences in the results obtained from the prisoners occupied in the two kinds of labour; and as one of the objects had in view was to show these differences, the two trades were selected which, in that prison, offered the greatest dissimilarity in the amount of exertion required.

Of these two sets of prisoners, the weavers of cocoa matting, when compared with the tailors, were older, taller, heavier, and broader; they ate more bread, milk, and water. They lost weight, whilst the tailors gained weight. They emitted more urine, urea, chloride of sodium, and fæces with their contained nitrogen; they exhibited much less diminution of urea on the Sunday, and a little less urea to body-weight.

It is not possible to compare the results of this inquiry very closely with those already described at Coldbath-fields, since in the latter inquiry the quantity of bread and water was rigidly fixed, whilst in the former there were daily variations. The quantity of bread taken was greater at Wakefield than at Coldbath-fields, and would so far increase the amount of urea produced, whilst the variable quantity of water taken from day to day would vary the elimination of that product. Yet these causes of variation are not of great value, and upon the whole it will be seen that there is a very close correspondence between the products of the weavers at Wakefield and those who worked the treadwheel at Coldbath-fields.

The weight of the men at Wakefield was more than that at Coldbath-fields, the quantity of urine and of fluid drank was less, and that of urea was greater, but the proportion of urea to body-weight was very nearly the same. In both there was more urea with labour, and less on Sunday. There was less chloride of sodium in the urine as there was less supplied in the food. The weight of the fæces and the contained nitrogen were the same in both places.

Conclusion.—The Committee cannot close this first part of their report without offering a few remarks in the nature of deductions or suggestions, but, inasmuch as the duty confided to them is limited to a consideration of the influence of prison discipline over the bodily functions of the prisoners, and the present is only a part of their report, they feel that they cannot express their views at any length.

The Committee venture to think that the time is approaching when the whole subject of prison discipline must be reconsidered, and when a determination may be arrived at as to the propriety of continuing a system which when practised occasions vast waste of the vital powers of the prisoners, and vast expenditure of money to provide a dietary which, although scarcely sufficient, is far beyond that provided for the poor in workhouses, and beyond that obtained by the working classes in general. The different systems adopted in prisons are furnishing some evidence as to the relative value of three plans,—viz., 1st, waste of animal force by the treadwheel and the crank; 2nd, the use of manufacturing operations; and 3rd, the effect of simple detention and instruction without labour; and these, when conjoined with the intelligent efforts put forth in the sister island, may almost suffice to guide those to whom its consideration may be intrusted.

It is, however, certain that if much bodily labour be enforced, whether in a profitable or unprofitable manner, there must be an expensive dietary to supply the reparative material; and no plan can be so wasteful as that which enforces profitless labour, and supplies an expensive diet to meet its demands.

The Committee also think that some steps should be taken to ensure uniformity in prison discipline throughout the kingdom; so that not only should great care be exercised (as at present) to apportion the sentence to the crime, but also that wherever the sentence is pronounced the carrying-out of it shall be also proportioned to the crime. This may be effected in the dietary, and yet allow such a variety of food as may be found relatively economical in different parts of the kingdom; for the nutritive value of various kinds of food is now tolerably known, and the quantity of each to give the same nutriment may be estimated. So also in reference to punishments. It is quite possible that the instruments should be of uniform construction, that by supervision they should be kept in uniform order, that the speed at which they are worked should be uniform, and the amount of a day's work should be universally the same, subject only to the opinion of the Surgeon as to the fitness of any individual to perform the required task. A committee of scientific men would find no difficulty in placing all this upon a satisfactory basis, if they were only authorized by the Government to do so.

It is also easy to estimate the amount of labour required in ordinary manufactures, at least so far to keep within the bodily powers of the prisoners; for we have the advantage of common experience as to the effect of such labour in ordinary life. But the Committee are of opinion that, when all the above-mentioned care shall have been taken, the effect of the proper prison punishments, as the treadwheel, crank, and shot-drill, upon the prisoners will still be very unequal, since it varies greatly with such natural conditions as the height, weight, age, and previous occupation of the person. Hence these punishments must be at all times objectionable.

The Committee defer until another occasion their recommendations in reference to the exact adaptation of labour to supply of food; but they take this opportunity of stating that, as it involves the fundamental question of the propriety of making the dietary an instrument of punishment, it will be necessary *in limine* to decide the latter question. When Sir James Graham appointed the Commissioners to draw up the present scheme of dietary, he expressly directed that the dietary should not be used as an instrument of punishment; but the Committee venture to affirm that the food supplied in the lowest scale is so totally unequal to the wants of the system, that it can only be regarded as an instrument of punishment; and that it is so regarded both by criminals and magistrates may be inferred from the dislike which old offenders have to short imprisonment with its low dietary, and from the value which magistrates attach to this their most formidable agent.

Without expressing a strong opinion upon this point, the Committee venture to assert that a dietary of bread and water, or bread and gruel, cannot be enforced without doing serious injury to the prisoner's health; and that this is fundamentally recognized may be inferred from the fact that all agree that a high scale of dietary is absolutely demanded in long imprisonments. The Committee assert that the injury is one of degree, and that the shortness of the imprisonment prevents the ill effects being observed, which with a long imprisonment have been proved to increase the mortality in gaols.

The Committee hope that, on philanthropic grounds, the principle may be established in prison discipline, that the prisoner shall not be so treated that when he leaves the gaol he shall be less able to earn his living than he was when he entered it, and that, punishment and reformation being sought together, some plan may be adopted which shall accord with that principle.

The fundamental fact of the duty of apportioning food to the labour performed needs to be re-established. At present the attempt is nugatory; but the Committee venture to hope that the principle will meet with universal concurrence, and that their labours afford at least some of the means whereby the estimation may be made.

The great value of the system of extra dietary cannot be too highly estimated; but the very admission implies that there is a defective adaptation of the general scheme of dietary to the wants of the system, and that almost the life of the prisoner is, throughout a large part of the imprisonment, at the discretion or negligence of one officer, viz. the Surgeon.

The Committee also venture to affirm that bread is far inferior to milk as an article of extra diet, as the experiments detailed in this report prove. The detention in prisons certainly lessens the power of assimilating food; and hence it is quite possible that whilst a given quantity of food would sustain a man out of gaol, it would not sustain him with the same labour in gaol. The object of extra diet is not so much to give additional material, as to give the kind of food which will aid the system in making a better use of that ordinarily supplied. Extra diet of bread (when the dietary is the highest scale) is in great part wasted, and increases disproportionately the amount of waste passing off by the bowel.

In conclusion, the Committee urge the great importance of making better use than heretofore of the unparalleled opportunities which prisons afford of working out the most important and difficult questions in nutrition, with a view to supply information for the more just and economical management of gaols, and for the advance of a science which is so essentially connected with the daily life of the community. Such questions are, the true value of white bread over brown bread in prison and other dietary; the exact influence of various kind of food, and especially of such as tea, coffee, milk and alcohol, which act chiefly by modifying the action of other food; the exact relation of a given quantity of food to a given amount of labour; the causes of the defective power of assimilation of food in prisons, and the relation of the elements of the food taken to those which are fixed in and thrown out of the body. The Committee feel that the importance of such inquiries is not by any means so well understood as it should be, and that some officials have a natural repugnance to anything which may interfere with their ordinary routine; but they trust that the expression of the opinion of this great Association, and the additional knowledge which they and others have endeavoured to discover, may open prisons to such inquiries.

The Committee will cheerfully undertake to lend their aid in further elucidating these matters, if it should be the pleasure of the Association to reappoint them; but they very respectfully represent the urgent necessity which exists for the appointment, by the authority of Government, of one or more Commissioners to reconsider the subject of dietaries, and to recommend plans whereby uniformity in the nature and action of the instruments used in prison punishments may be effected throughout the kingdom.

APPENDIX I.

On the Inequalities in the Dietary of County Prisons; being an Analysis of the "Return of Dietaries for Convicts," &c., issued in 1857*.

Forty-three only of eighty-seven county prisons have adopted the scheme of dietary recommended by the Government; and in reference to the forty-four prisons which dissent from that scheme, it will be evident, from the following statement, that much of the inequalities in their various dietaries is attributable to the defects of the Government scheme, much to mere caprice, something to very defective knowledge as to the requirements of the human system, and something more to the absence of a desire to avoid injury to the prisoner. We shall first give in a few words the dietary of the Government scheme, and then describe the dietaries of all the prisons which have striking peculiarities.

There are five classes of dietaries recommended by the Government, according to the duration of the sentence, and such that the quantity and quality of food are increased from the beginning of the imprisonment as the duration of the sentence is increased.

Up to twenty-one days, only bread and gruel are given, but under seven days the bread (1 lb.) is given at dinner only, whilst over that period twenty-four ounces are distributed over the three meals. Under seven days, females receive as much bread for dinner as the males; but over that period they receive but half the quantity.

From twenty-one to forty-two days with hard labour, and to four months without hard labour, three ounces of cooked meat with bread and potatoes are given for dinner twice per week, one pint of soup (containing the same quantity of meat) with bread twice, and simply bread and potatoes thrice per week.

From forty-two days to four months with hard labour, and beyond four months without labour, three ounces of meat is given daily in soup or otherwise.

Beyond four months with hard labour, the quantity of meat is increased four times per week to four ounces, and an increase of half a pound of potatoes is added,—soup, potatoes, and bread being supplied on the other days. Sweetened cocoa for breakfast is also given thrice per week.

The erroneous principles upon which this scheme is founded are, the apportionment of food according to duration of sentence, the insufficiency for short sentences and for hard labour, and the variation from day to day; but

* It is probable that some changes have been made in the dietaries of some of the County Gaols, and particularly in those marked with an asterisk (*), since the return of 1857 was issued, and since the following analysis was made; but of this there is no authorized information. The analysis will, at least, show the state of the dietaries when the return was issued.

having already pointed them out in a paper published in the Transactions of the Society for the Promotion of Social Science, we shall not pursue that subject on this occasion, but at once proceed to consider the dietaries opposed to this scheme.

The Welsh gaols, as a whole, have a reduced scale of dietary; but one of them, viz. the Cardiff Gaol*, is the most remarkable in the deficiency; whilst another, the Brecon Gaol, is nearly equally remarkable for its plenty. It is instructive to notice how widely the schemes differ under different administrations, whilst the condition of the inhabitants of the localities must be much the same. In the Cardiff Gaol there are four classes of prisoners, the highest including all those condemned for periods exceeding fourteen days, a term scarcely equal to the second class of the government dietary, and even in that no meat or other animal food in any form is given. For breakfast and supper there is half a pound of bread and two ounces of oatmeal made into gruel, whilst at dinner there is only half a pound of bread and one pound of potatoes. But if the prisoner should be condemned to hard labour he will receive one pint and a half of soup, made from two ounces of Scotch barley and two ounces of rice, and it is the same whether he is condemned to hard labour for fifteen days or fifteen months! If the prisoner is condemned for more than seven and less than fourteen days, he receives for dinner half a pound of bread only. If not exceeding three days or seven days, the breakfast and supper consist of half a pound of bread only, whilst the dinner is composed of half a pound of bread, and in the latter case of one pound of potatoes in addition. Thus, if he be confined for three days or for fourteen days, half a pound of bread only is sufficient for the dinner; but, if it be for seven days, he is supposed to need one pound of potatoes in addition! This is the worst dietary in the whole of the county gaols; but the dietary of the Derby Gaol* shows that Englishmen as well as Welshmen are sometimes fed with the almost entire absence of animal food. The Derby dietary is divided into three classes; but we are not favoured with the grounds of this division. In the first class there are six ounces of bread and one pint of porridge for breakfast, whilst in the second and third classes the quantities are increased to eight ounces and one pint and a half. The word *porridge* does not imply that excellent article which we remember to have enjoyed in boyhood, but it consists of a quarter of a pint of milk and three-quarters of a pint of water, and one ounce and a half of oatmeal, instead of two ounces ordered by the Government to each pint of gruel. The supper consists of four ounces of bread and one pint of gruel (we are not informed as to the ingredients of the gruel) for the first class, six ounces of bread and one pint of porridge for the second, and eight ounces of bread and one pint of porridge for the third. The dinner in the first class is ten ounces of bread only; in the second class there are eight ounces of bread and one pound of potatoes five times per week, and eight ounces of bread and one pint of soup twice per week (the excellence of the soup is not stated); in the third class eight ounces of bread and two pounds of potatoes! twelve ounces of bread and one pint of soup thrice, and twelve ounces of bread and four ounces of meat once per week. The points of greatest interest are the excessive amount of farinaceous food, and the great defect of animal food. There is also a note appended to this return, stating that cases do *sometimes* occur of prisoners losing weight! If in the Wakefield Prison, to which we shall refer presently, a very large number of the prisoners lose weight under the best management, and with a much better etary, it is not wonderful that at Derby they should lose weight *sometimes*. We should be glad to know if they are weighed accurately and periodically; if they enter the prison having an average weight; what percentage in each class lose weight during their imprisonment; and what is the tone of their muscular system on discharge? The note also states that when they lose weight the surgeon orders them to have extra milk, or bread, or meat. But essential articles of diet should not be left to the chance of the negligence or indiscretion of even the best of men.

The Brecon Gaol offers a contrast to both of the foregoing. Thus, for periods exceeding fourteen days, the prisoner receives six ounces of meat with eight ounces of bread on four days in the week, and also half a pound of potatoes if under, and one pound of potatoes if over, two months. On the other days the dietary is only bread and potatoes. For breakfast and supper the dietary for all periods is eight ounces of bread and one pint of gruel, but on alternate days the oatmeal is boiled in the meat liquor. There is also a further advantage given in substituting for potatoes, when they are bad, four ounces of rice and *one ounce of treacle or sugar.* The Middlesex prisons also give six ounces of meat at one meal. In the Coldbath-fields Prison, and the House of Correction, Westminster, twenty ounces of bread are equally divided between the three meals. There is also a pint of cocoa to the highest class (exceeding two months) and one pint of gruel to others; for breakfast; whilst at supper there is one pint of gruel to the highest class, and half a pint to others. The dinner, besides bread, contains, in the highest class, six ounces of meat and eight ounces of potatoes four times per week, or one pint and a half of soup thrice per week. In the second class (two weeks to two months) there is the same quantity of meat and potatoes twice, one pint of soup twice, and one pint of gruel thrice per week. But in the lowest class it consists of bread and gruel only.

The Lincoln House of Correction at Spalding has also a dietary better than that recommended by the Government, since, in addition to the meat, there is allowed one pint of soup; but the ingredients of the soup are not stated. It has also the advantage of giving meat daily in the fourth and fifth class, apart from the soup, and thus the important article of diet is evenly distributed; and since the soup is probably made from the meat liquor, it increases the quantity of fat which is supplied to the prisoners.

The Newgate Prison, Lincoln Castle, and the Pembroke Gaol are remarkable in having but one scale of dietary each for all the prisoners, thus avoiding the fallacy which results from varying the dietary according to the term of imprisonment. They, however, differ very much in the quantity and quality of food which they deem to be proper for their prisoners. Thus the Newgate Prison and Lincoln Castle adopt Class 4 of the Government scheme. The Pembroke Gaol affords only one quart of oatmeal gruel (the quantity of oatmeal is not stated) and three-quarters of a pound of bread for dinner. At breakfast there is a luxury found only at this gaol, viz. tea and butter; so that the meal consists of *a pint and a half of tea, one pound of bread, and one ounce of butter.* The supper is composed of one quart of milk pottage (the constituents are not given) and three quarters of a pound of bread. This is a remarkable dietary, and one which on paper must be very satisfactory, except in the absence of animal food. A foot-note states that "the surgeon orders extra food when necessary;" but the nature of the food which he may order is not stated. The largest quantity of bread is contained in this dietary, viz. two pounds and a half of bread daily. We should like to know the result of the entire avoidance of fresh vegetables, a circumstance also peculiar to this prison, if the return be true.

Another peculiarity is met with in the three Gloucester gaols (one of which, the House of Correction at Horsley, is under the direction of a name well known in prison management), viz. the exhibition of the same food on each day of the week. The plan of varying the food with the class is pursued, but, with the exception of the third class, the food is not varied from day to day. In the lowest class the food is simply eight ounces of bread at each meal. In the second class one pint of gruel is added to the breakfast and supper. In the third class eight ounces of potatoes are added daily, and three ounces of meat twice in the week. In the fourth and fifth classes the meat is given daily, and in the fifth class the potatoes are increased to one pound. There is also another point worthy of notice which is peculiar to these gaols and the Lincoln House of Correction, Spalding, viz. the administration of meat on every day in the week to the two highest classes, apart from or to the exclusion of soup. There are thus two important circumstances redounding greatly to the credit of those who have the supervision of these institutions in the county of Gloucester.

The peculiarity of administering the same food on each day of the week is also met with at the Cardiff, Flint, Sussex, and Wilts gaols. The poverty of the Cardiff dietary has already been stated, and the Flint Prison dietary is very far removed from liberality. Thus for fourteen days it affords simply one pound of bread and four ounces and a half of oatmeal daily. For six weeks, one pound and a quarter of bread, four ounces and a half of oatmeal, and half a pint of milk daily, and for all periods beyond six weeks a quarter of a pound of bread is added daily, and two pints of soup per week.

The Sussex Prison at Lewes gives to all classes half a pound of bread and one pint of gruel for breakfast and supper. For fourteen days the dinner is eight ounces of bread only; for six weeks one pint of soup is added on three days per week; for four months the soup is given daily; and for all periods beyond, one pound of potatoes is added daily. The dietary at Petworth is more liberal. Thus, after one month the dinner consists of half a pound of bread, four ounces of meat, and one pint of soup; and after three months, one pound of potatoes is added daily. The dinner at this prison is therefore very excellent after the expiration of the first month. The two county gaols in Wiltshire have the same dietary. All prisoners not sentenced to hard labour receive one pound and a half of bread and one pint of gruel daily, and after fourteen days have one pint of soup in addition. This is all the dietary with hard labour from fourteen to forty-two days: viz., to fourteen days with hard labour the dietary is simply one pound and a half of bread and one pint of gruel daily; from six weeks to three months one pint of soup is added daily from the commencement; and when the term exceeds three months, one pound of potatoes is given daily after three months. This scheme is not equal to the Government allowance.

The dietary in the Lancaster House of Correction at Preston varies chiefly, but not exclusively, with age, viz. under æt. thirteen, under æt. seventeen, and over æt. seventeen. In these, the breakfast and supper consists of four ounces of bread and one pint of gruel, six and two-thirds ounces of bread and one pint of gruel, and six and two-thirds ounces of bread and two pints of gruel respectively.

The dinner of the first class is four ounces of bread and one pint of gruel thrice; four ounces of bread, four ounces of meat, and one pint of soup once; four ounces of meat and half a pound of potatoes once; four ounces of bread and one pint of soup once; and the singular combination of half a pound of potatoes with one ounce of cheese once per week. In the second class the scheme is varied simply by the administration of six and two-thirds ounces of bread daily; and the third differs from the second in doubling the quantity of potatoes, cheese, gruel, and soup. The soup, however, does not contain meat, and the gruel is very poor.

There are certain limitations, depending upon the duration of the sentence. Thus, for seven days the diet is twelve to twenty ounces of bread daily. For fourteen days boys and girls receive half of the second-class rations, and for a month adults have half of the third-class rations. There is also a great and unique curiosity in the list of limitations which refer to itch patients, who receive but twelve ounces of bread per diem, whether as a punishment or a cure for their uncleanness is not stated. We cannot but regard this as a meagre dietary, since we cannot tell in what degree the discretionary power, which a foot-note states to rest with the governor and surgeon, in increasing the dietary after three months' imprisonment, is exercised, and, so far as adults are concerned, it appears that the only increase which can be made extends to ten ounces of bread only.

A gaol which has for its governor another gentleman of the name of Shepherd, viz. the Wakefield Gaol, is also remarkable in its dietary, but in a different direction from any of the foregoing. The peculiarity is in the greater variety of food and the care which is taken to make it palateable. The distinction into classes is maintained, and in the highest classes is so extended that it begins only after twelve months' imprisonment. The breakfast and supper are alike, except in the highest class, and consist of one pint of gruel only in the first class (seven days), whilst in the second and third six ounces of bread are added; in the fourth class eight ounces of bread are allowed, and in the fifth class the same quantity of bread is allowed, and milk substituted for gruel for breakfast, but not for supper. The dinner in the first class is one pound of bread. In the second class it consists of half a pound of bread and one pound of potatoes twice, four ounces of bread, with one pint of pea-soup or a pint and a half of gruel twice, plain pudding and one ounce of treacle twice, and twelve ounces of bread alone once per week. In the third class the bread and potatoes alone is restricted to once per week; four ounces of bread, one pound of potatoes, and three ounces of cooked meat are given once; four ounces of bread, a plain pudding, and one ounce of treacle once; whilst four ounces of bread and one pint of soup, pea-soup, or Irish stew, are given four times per week. In the fourth class the bread, meat, and potatoes are given twice (once being instead of bread and potatoes alone), the other diets remaining the same. In the fifth class the bread, meat, and potatoes are given thrice, the same with half a pint of soup added twice, and bread and Irish stew alone twice per week. The soup does not contain meat, but is made from meat liquor, oatmeal, and vegetables. The pea-soup has the large quantity of six ounces of peas and four ounces of carrots per pint, with mint and pot-herbs. The Irish stew contains three or four ounces of meat with sixteen ounces of vegetables. The plain pudding is a quart made from eight ounces of flour. As the soup is partly made from bones, which are boiled for twenty-four hours, it contains a very essential article in abundance, viz. fat. Altogether, this is not only the most elaborate dietary in the return, but it seems to be the *ultima Thule* in that direction, and whatever may be its defects, it certainly evinces an anxious desire not only to feed the prisoners sufficiently, but to treat them with the consideration due to beings who have the sense of taste. Yet with this dietary, and with the entire absence of the treadwheel and the crank labour, a very large proportion of the prisoners are reported weekly as losing weight.

The Hertford Gaol at St. Albans * offers some peculiarities by which it might have been ranged with the foregoing, but it has one which is quite distinctive, viz. *the absence of supper.* The hours of meals are not given; but the fact is stated that only breakfast and dinner are allowed, even to those condemned to hard labour, both males and females. Surely this is cruelty, and must result from gross ignorance of the wants of the system and the responsibilities of those who devised and retain the plan. If there is no excess of food left over from the previous day, in those prisons where a meal is given at 6 P.M., upon what do the St. Albans prisoners sustain the exertion of hard labour before the breakfast, when the previous meal was the dinner on the previous day? If sleeplessness results from both repletion and want of food, we should like to know how deep is the repose of the Hertfordshire felons. The unenviable refinement to which we have referred is also further seen in the absence of division of the classes by time, so that all the prisoners are fed alike during the first week of imprisonment, whether they are sentenced to hard labour or not, and for whatever duration; and after the first week the dietary is the same, except that it is varied in reference to labour, and further varied in reference to the sex condemned to hard labour. Thus there is no increase in the dietary, and hence the nature of that dietary is of vast importance. The breakfast uniformly consists of twelve ounces of bread and a pint of gruel, except when associated with hard labour, when there are sixteen ounces of bread for the men. The dinner consists of twelve ounces of bread and one pint of soup (the ingredients are not stated) four times, and twelve ounces of bread alone thrice per week. To females condemned to hard labour, the soup is given daily, and there is a further addition for males of four ounces of bread. There are thus one pound and a half or two pounds of bread given daily as in other schemes of dietary, but it is ill distributed, and whilst there are several points in the dietary to be commended, the absence of supper deserves condemnation. As a contrast to this we may refer to the Welsh gaol at Carnarvon, in which supper is not only allowed, but it is enriched by the addition of a pint to a pint and a half of broth; but to this we shall again advert.

We may now consider certain peculiarities in reference to the articles of food supplied, which have a certain degree of interest, and in a few instances affect an important principle.

In the four Northumberland gaols the quantity of oatmeal is increased and given as porridge where the Government has recommended simply gruel. This contains six ounces of oatmeal, instead of two ounces, as ordered for gruel, and milk or treacle water. There is also one pound of suet pudding given in the third, fourth, and fifth classes in place of the meat, bread, and potatoes recommended by Government. It may be questioned if one pound of suet pudding is equal to three ounces of cooked meat without bone, half a pound of bread, and half a pound of potatoes; and as the quantities of the component articles are not stated, we cannot determine such an inquiry. It has, however, this merit, which involves a principle so much neglected in prison dietary, viz. the administration of fat with the starch, and is therefore so far to be commended. It is also to be noticed to the credit of these institutions, that the dietary of the first two classes is better than that recommended by the Government, since in the first class each prisoner receives eight ounces additional oatmeal, besides milk, and in the second class there is an addition of eight ounces of potatoes to the dinner. In the return of the Alnwick House of Correction there is no provision made for prisoners sentenced to a larger term of imprisonment than six weeks, and there is specific mention of half a pint of milk in addition to one pint of porridge for the breakfast and the supper, but no bread is allowed at those meals.

The other north-country gaols, of Cumberland and Westmoreland, also make large use of oatmeal and milk in their schemes of diet, and the scheme is the same in both gaols. The quantity of bread is reduced, and to so reprehensible a degree that, for prisoners confined from seven to fourteen days, four ounces of bread alone constitute the whole dinner,—a quantity of food less than is supplied at any other prison. For seven days six ounces of bread are given at each meal; with hard labour for six weeks, and no labour for three months, one pint of soup is added to the dinner thrice, one pound of potatoes thrice, and three quarters of a pint of milk once per week; and when the terms are increased to three months, and beyond three months respectively, three ounces of cooked meat and half a pound of potatoes are given, instead of one pound of potatoes, twice per week. When the sentence of hard labour is beyond three months, four ounces of uncooked meat, four ounces of bread, and one pound of potatoes are given for dinner thrice per week, whilst one pint of soup supplants the meat thrice per week, and three-quarters of a pint of milk and six ounces of bread constitute the Sunday's dinner. The use of oatmeal is restricted to the breakfast and supper, when four or five ounces, with half a pint of milk, without bread, constitute the meal.

The Monmouth Gaol is also remarkable in the quantity of oatmeal supplied to the prisoners, and for the introduction of Indian meal as an article of diet. The two first classes are unchanged, except that the term of the second is extended to four weeks. In the third and fourth classes, which extend respectively to three months and beyond three months, the breakfast consists of no less than eight ounces of oatmeal and half a pint of milk, and the supper of six ounces of oatmeal with half a pint of milk and half a pound of bread. Both of these are largely in excess of the Government allowances, and approach much nearer to the wants of the system. The dinner in the third class consists daily of eight ounces of Indian meal and half a pint of milk, whilst in the fourth or highest class that food is administered on three days per week; four ounces of cooked meat, without bone, and twelve ounces of potatoes twice, and one pint of broth (containing three ounces of cooked meat without bone) twice in the week. We believe this to be a better dietary than that recommended by the Government; and a foot-note appended to the return is satisfactory on this head. It states: "The general health of the prisoners is good; and, *for the most part,* they leave the prison in better condition than when they came in. Prisoners of the third and fourth class are weighed on receipt and discharge; they are kept in association, and they almost invariably increase in weight while in prison." It would be interesting to know if they enter with an average weight.

A large division of the gaols which offer peculiarities of detail are the Welsh. We have already remarked that generally the dietary of the gaols of the Principality is less nutritious than that of English gaols, and we may further state that only three of the thirteen county gaols have accepted the Government scheme.

In the Carmarthen Gaol the prisoners condemned to hard labour for any term receive meat but twice per week; and that is in the form of soup, of which a quart is given; but the ingredients are not stated; twelve ounces of bread are given with it for terms exceeding two months. When the term exceeds three months two ounces of cheese and one pound of potatoes, or one pint of gruel, substitute the meat soup on three days per week; but no cheese is allowed for shorter periods; and thus a prisoner may be kept at hard labour for three months and receive twelve ounces of bread for dinner daily, with a quart of meat soup twice, and one pound of potatoes, and one pint of gruel each thrice per week. The breakfast and supper invariably consist of half a pound of bread and one pint of gruel.

The Carnarvon Gaol introduces a new article of diet, and is unique in this particular, viz. buttermilk, one pint of which is added to the dinner twice per week. The whole dietary differs from that recommended by the Government, and is a subject on which the authorities of the gaol have either doubt or pride, if we may judge by the multitude of certificates which they have been pleased to append to the return. In all the classes a pint to a pint and a half of broth is administered for supper thrice per week instead of gruel, and given alone in the first two classes, but with six or eight ounces of bread in all the others. This is made from the meat liquor, with two ounces of peas, and with green vegetables, and is, therefore, a very valuable addition to the dietary. There is a diminution in the quantity of bread and an increase in that of potatoes in the proportion of two ounces of the former to half a pound of the latter. Soup is given on three days per week to prisoners condemned for periods exceeding twenty-one days; but no meat is allowed separately, except for longer periods than three months, and then three ounces of meat are given separately on three other days per week. Taken as a whole, it is an improved dietary.

The dietary of the Merioneth Gaol at Dolgelly is full of peculiarities. It introduces four new articles of diet, viz. cheese, bacon, milk, and boiled rice; but they are not all given on one day or on any fixed rota, but each is contingent: so that three ounces of bacon meat, without bone, may be substituted for eight ounces of bread and four ounces of cheese, or one quart of pea-soup or broth, and four ounces of bread; and one pound and a half of boiled rice is regarded as an equivalent for the bread and cheese in one place, and for half a pound of bread alone in another. One quart of milk and eight ounces of bread may be substituted once per week for any of the above dinners. Excepting these various contingencies, which give a complex air, the scheme is simple; for it only provides for two classes, comprehending prisoners condemned, respectively, to fourteen and exceeding fourteen days, without labour; so that a plain bread-and-cheese dinner, or any of the above-mentioned alternatives, is considered sufficient for dinner for any period, however long. Broth or soup is given for dinner to the first class. The gruel, broth, and pea-soup are each weaker than the gruel and soup recommended by the Government. We cannot but regard this dietary as defective in having so many contingencies, and those which differ much in nutritive value, whilst they are regarded as good substitutes for each other; but since the average use of each kind of diet is not stated, it is impossible to estimate the true value of this dietary. The extra food allowed for hard labour is ridiculously insufficient, viz. six ounces of bread per day; and the whole scheme demands immediate revision.

The Montgomery Gaol also provides bacon as an article of diet to the highest class, or those exceeding three months' imprisonment. The quantity allowed is two ounces without bone, added to one pound of potatoes and half a pound of bread four times per week, whilst on other days the dinner consists of one pint of soup and half a pound of bread. For periods varying from two weeks to three months, the bacon is omitted. In the first class, one pint of soup is given on the Sunday, whilst on other days the dinner consists of half a pound of bread only. Bacon as an article of prison dietary is valuable, since it supplies fat, and is also savoury.

The Denbigh County Gaol at Ruthen introduces us to another novelty, viz., scouse, which is composed of beef cut into small pieces, and potatoes, in such proportion that one pound and a half of scouse contains 2·18 ounces of meat. This has the very patent evil of inaccurate division to each prisoner. The whole dietary is very meagre, since, for all prisoners condemned to an imprisonment exceeding a month, the dinner thrice per week is one and a half pound of scouse, half a pound of bread, and one pound of potatoes four times per week. When the term does not exceed one month, the dinner is composed of five and one-third ounces of bread and one pound of potatoes, whilst for seven days five and one-third ounces of bread only constitutes the dinner.

In the Glamorgan Gaol at Swansea, the prisoner sentenced to more than one month's imprisonment receives a bread-and-cheese dinner, as at some other Welsh gaols; but in this one pound of potatoes is added. This is given thrice per week, whilst half a pound of bread and a pint and a half of soup, containing four ounces of *coarse* meat, are given four times per week. No meat and cheese are allowed for a less period than one month.

Space will not permit us to continue the analysis of these returns further; but we may remark that at the Bucks and some other county prisons no extra food for hard labour is stated in the return; at the Dorset Gaol, a bread-and-cheese dinner is provided three times per week for the highest class; at Durham the dietary is reduced in value for periods up to six months; at Huntingdon there are some meaningless changes in reference to the quantity of bread allowed; at the Southampton Gaol, three ounces of cheese are considered an equivalent for one pint of soup containing four ounces of raw meat without bone, four ounces of potatoes, one ounce of rice, &c.; and at Devon, the soup contains but two ounces of raw meat per pint.

We have thus made it very evident that uniformity in dietary is not one of the characteristics of our prisons, and that those who are condemned to imprisonment receive very different treatment in different parts of the kingdom. Indeed the diversity is so great, that it would be in vain to prepare a tabular statement of the dietary of the forty-four prisons of such moderate dimensions, and with so much approach to uniformity, that even the most painstaking student could study it with the hope of understanding it; for it would be impossible to reduce the return to more general forms, with a view of comparing them and committing them to memory.

Appendix II.

Punishments and Dietaries of Prisoners,—Address for Returns of the punishments inflicted under sentences to "hard labour"—

Of the working of the treadwheel;

Of the pressure and working of the crank;

Of the weight of Prisoners, and the variations of it due to treadwheel and crank labour;

in the City, Borough, and County Gaols of the United Kingdom:

And, of the Dietaries sanctioned for Prisoners in the City and Borough Prisons of the United Kingdom, and in those County Prisons of the United Kingdom in which the Dietary has been changed since the Return of "Dietaries for Convicts, &c." ordered by the House of Commons to be printed, 21st day of March, 1857, or in which the Dietary is not correctly set forth in that Return:—

Hard Labour.					Treadwheel.											Crank.							
The punishments employed.	The order in which they are used.	The length of time during which each is inflicted.	Men.	Women.	Height of step in inches.	Number of steps ascended per minute.		Hours of treadwheel labour.	Hours of intermission.	Total time upon the wheel daily.	Total height in feet ascended daily.		Is each Prisoner upon the wheel daily.	Mode of regulating the rapidity of the revolution of the wheel.	Are all the places upon the wheel always filled.	Various amounts of pressure in lbs. required to move the cranks.	How is the pressure estimated and regulated.	Are the cranks periodically inspected and kept in easy working order.	Is the index within sight of the Prisoner.	Ordinary number of revolutions per day with different pressures.	Grounds and authority for variation from the ordinary number.	Length of handle of the crank in inches.	Hours of commencement and termination of the day's labour.
						In Summer.	In Winter.				In Summer.	In Winter.											

Weight.															
Hour of weighing.		Is the weight of the clothes deducted.	Kind of balance, and weight required to move it when loaded with a man.	Prisoners received in 1858, 1859, and 1860, of each age on entrance.				Number weighed.	Total weight in lbs. on entrance.	Total gain in lbs. on discharge.	Total loss in lbs. on discharge.	Average loss of weight with Treadwheel or Crank labour of all prisoners in 1860, committed with sentences of			
On entrance.	On discharge.			16 to 25.	25 to 35.	35 to 45.	45 and upwards.					1 month and under.	1 to 2 months.	2 to 3 months.	3 to 4 months.

Dietaries for Convicted Prisoners, in City and Borough Prisons, and in those County Prisons in which the Dietary has been changed since the Return of "Dietaries for Convicts, &c." ordered the 27th day of February, 1857.
Total quantities per week in each Scale of Dietary, in ounces and parts of an ounce.

Scale No.													Milk.											Other articles of dietary.					
	No. of scale of dietary.	Duration of sentence under each scale.	On what scale commence.	Nos. of scale with treadwheel and crank labour.	Meat, cooked, and without bone.	What joints are supplied.	Bacon cooked.	Bread.	Oatmeal.	Rice.	Potatoes.	Other fresh vegetables.	Dried peas.	New.	Skimmed.	Cocoa, solid.	Tea, dry.	Coffee, dry.	Sugar.	Molasses.	Kitchen salt.	Fat, other than in the meat.	Water, in imperial pints.	Beer, in imperial pints.					Total solids.	Total fluids.
1																														
2																														
3																														
4																														
5																														
&c.																														

APPENDIX VI.—West-Riding Prison, Wakefield.

A Table showing the average Weight of Prisoners on Receipt and Discharge in each Class of Diet. (Taken for Two Years.)

	Number of Prisoners weighed.	Average weight on Receipt.	Average weight on Discharge.	
1856.		lbs.	lbs.	
Table 1....................	64	113·7	112·9	
„ 2....................	1030	124·3	122·4	
„ 3....................	757	121·5	119·6	
„ 4....................	156	128·5	129·4	
„ 5....................	48	127·6	125·9	
	2055	123·45	121·80	
1860.				
Table 1....................	174	128·9	128·0	
„ 2....................	1091	124·1	121·8	
„ 3....................	799	121·1	118·3	
„ 4....................	108	126·7	125·4	
„ 5....................	72	125·4	126·5	
	2244	123·50	121·29	

A Statement of the Number and Weight of Prisoners employed at the Treadmill in the West-Riding Prison at Wakefield. (Total of Classes.)

Weeks on Treadmill.	Persons.	Loss in lbs.	Average loss in lbs.	
One week on Treadmill........	41	108	2·63	
Two weeks „	26	119	4·57	
Three weeks „	10	60	6·0	
Four weeks „	5	38	7·7	

APPENDIX III.—A TABLE showing the average Loss in Weight per Male Prisoner in Nine Years, in each Class of Dietary during years 1852 to 1860, inclusive, together with a Summary of the whole. (West Riding Prison, Wakefield.)

Diet Tables.	1852.			1853.			1854.			1855.			1856.		
	No. Prisoners.	lbs. Loss.	Average Loss.	No. Prisoners.	lbs. Loss.	Average Loss.	No. Prisoners.	lbs. Loss.	Average Loss.	No. Prisoners.	lbs. Loss.	Average Loss.	No. Prisoners.	lbs. Loss.	Average Loss.
1	75	109	1·4	89	150	1·7	90	99	1·1	98	127	1·3	64	53	0·8
2	1378	4558	3·3	1227	4584	3·7	1158	3755	3·2	1145	2562	2·2	1030	1963	1·9
3	818	3264	3·9	765	2978	3·9	828	2599	3·1	823	1657	2·0	757	1445	1·9
4	141	532	3·8	144	531	3·7	171	443	2·6	129	326	2·5	156	136 Gain	0·9
5	74	201	2·8	71	223	3·1	77	51	0·6	61	200	3·3	48	81	1·7
	2486	8664	3·5	2296	8466	3·68	2324	6947	3·0	2256	4872	2·26	2055	3406	1·65

Diet Tables.	1857.			1858.			1859.			1860.		
1	97	158½	1·6	106	63	0·6	107	101	0·9	174	164	0·9
2	1149	2186	1·9	1313	2870	2·2	1133	2275	2·0	1091	2612	2·4
3	925	1681½	1·9	890	2334	2·4	807	2379	2·9	799	2223	2·7
4	198	296 Gain	1·5	156	181	1·2	131	33 Gain	0·2	108	139	1·2
5	58	93 Gain	1·6	75	233 Gain	1·8	92	93 Gain	1·1	72	80 Gain	1·1
	2427	3637	1·49	2540	5215	2·0	2270	4629	2·0	2244	5058	2·21

	Years.	No. Prisoners.	lbs. Loss.	Average Loss.	Years.	No. Prisoners.	lbs. Loss.	Average Loss.
Summary............	1852	2,486	8,664	3·5	Brought forward	11,417	32,355	—
	1853	2,296	8,466	3·68	1857	2,427	3,637	1·49
	1854	2,324	6,947	3·0	1858	2,540	5,215	2·0
	1855	2,256	4,872	2·26	1859	2,270	4,629	2·0
	1856	2,055	3,406	1·65	1860	2,244	5,058	2·21
		11,417	32,355	—		20,898	50,894	2·4

APPENDIX IV.—Showing the relation of Weight to duration of Imprisonment.

Stage of Imprisonment at Wakefield.	No. of prisoners weighed.	Number of Prisoners			Percentage of Prisoners			No. of Pounds		Net		Average				Percentage placed on extra diet.
		Gaining weight.	Losing weight.	Stationary.	Gaining weight.	Losing weight.	Stationary.	Gained.	Lost.	Gain.	Loss.	Gain per prisoner gaining.	Loss per prisoner losing.	Gain per prisoner weighed.	Loss per prisoner weighed.	
First & second mo.	7980	3901	3374	705	48·9	42·3	8·8	10038·0	8108·5	1929·5	—	2·57	2·40	0·24	—	3·14
Third & fourth „	7880	2988	4141	751	37·9	52·6	9·5	5769·0	9383·0	—	3614·0	1·93	2·27	—	0·46	12·21
Fifth & sixth „	7663	3090	3833	740	40·3	50·0	9·7	6562·5	8186·5	—	1624·0	2·12	2·14	—	0·21	29·81
Seventh & eighth	6715	2968	3044	703	44·2	45·3	10·5	6477·0	6009·0	468·0	—	2·18	1·97	0·07	—	29·98
Ninth & tenth „	5211	2331	2319	561	44·7	44·5	10·8	5243·5	4630·0	613·5	—	2·25	2·0	0·12	—	15·98
Eleventh & twelfth	3277	1547	1363	367	47·2	41·6	11·2	3351·5	2800·5	551·0	—	3·17	2·05	6·17	—	8·88
Total	38726	16825	18074	3827	43·4	46·7	9·9	37441·5	39117·5	—	1676·0	2·22	2·17	—	0·04	100·00

APPENDIX V.—Showing the relation of Weight to Labour.

Employment in Wakefield Prison.	No. of prisoners weighed.	Number of Prisoners			Percentage of Prisoners			No. of Pounds		Net		Average				Percentage on extra diet.
		Gaining weight.	Losing weight.	Stationary.	Gaining weight.	Losing weight.	Stationary.	Gained.	Lost.	Gain.	Loss.	Gain per prisoner gaining.	Loss per prisoner losing.	Gain per prisoner weighed.	Loss per prisoner weighed.	
Coir-pickers	71	40	23	8	56·3	32·4	11·3	311·5	181·5	130·0	—	7·79	7·89	1·83	—	26·8
Tailors .... Shoemakers .... Miscellaneous	1411	812	524	75	57·6	37·1	5·3	5009·0	2601·5	2407·5	—	6·17	4·96	1·71	—	26·4
Carpenters .... Mechanics.......... Winders	269	147	107	15	54·6	39·8	5·6	960·0	637·0	323·0	—	6·56	5·94	1·20	—	36·8
Mat-makers .... Mat-weavers .... Canvas-weavers ... Mat-finishers ...... Coir-plaiters........	2064	826	1152	86	40·0	55·8	4·2	4555·0	6879·5	—	2324·5	5·51	5·97	—	1·13	39·4
Matting-weavers	185	37	145	3	20·0	78·4	1·6	180·0	1441·0	—	1261·0	4·87	9·94	—	6·81	60·1
Total.............	4000	1862	1951	187	46·5	48·8	4·7	11015·5	11740·5	—	725·0	5·92	6·02	—	0·18	35·3

APPENDIX VII.—Showing the relation of Weight to Age.

Age.	No. of prisoners weighed.	Number of Prisoners			Percentage of Prisoners			Number of Pounds		Net		Average				Percentage on extra diet.
		Gainn g weight.	Losing weight.	Station-ary.	Gaining weight.	Losing weight.	Station-ary.	Gained.	Lost.	Gain.	Loss.	Gain per prisoner gaining.	Loss per prisoner losing.	Gain per prisoner weighed.	Loss per prisoner weighed.	
17	62	37	22	3	59·7	35·5	4·8	273·5	99·0	174·5	—	7·39	4·50	2·81	—	
18	288	180	100	8	62·5	34·7	2·8	1098·0	430·5	667·5	—	6·10	4·31	2·32	—	
19	334	178	136	20	53·3	40·7	6·0	989·0	632·5	356·5	—	5·56	4·65	1·07	—	
20	330	150	161	19	45·5	48·8	5·7	801·0	816·5	—	15·5	5·34	5·07	—	0·05	
21—24	1059	444	577	38	41·9	54·5	3·6	2390·0	3518·5	—	1128·5	5·38	6·10	—	1·06	
25—30	940	438	460	42	46·6	49·0	4·4	2648·0	2999·5	—	351·5	6·05	6·52	—	0·37	
31—40	704	284	379	41	40·3	53·8	5·9	1830·5	2586·5	—	756·0	6·45	6·82	—	1·07	
41 and upwards	283	151	116	16	53·3	41·0	5·7	985·5	657·5	328·0	—	6·53	5·67	1·16	—	
Total	4000	1862	1951	187	46·5	48·8	4·7	11015·5	11740·5	—	725·0	5·92	6·02	—	0·18	

APPENDIX VIII.—Showing the relation of Weight to Height.

Height in Inches.	No. of prisoners weighed.	Number of Prisoners			Percentage of Prisoners			Number of Pounds		Net		Average				Percentage on extra diet.
		Gaining weight.	Losing weight.	Station-ary.	Gaining weight.	Losing weight.	Station-ary.	Gained.	Lost.	Gain.	Loss.	Gain per prisoner gaining.	Loss per prisoner losing.	Gain per prisoner weighed.	Loss per prisoner weighed.	
Under 59	20	10	9	1	50·0	45·0	5·0	57·5	40·0	17·5	—	5·75	4·44	0·87	—	20·0
59—62	567	278	267	22	49·1	47·1	3·8	1570·5	1332·5	238·0	—	5·65	4·99	0·42	—	25·9
63—66	2343	1123	1103	117	47·9	47·1	5·0	6351·0	6308·0	43·0	—	5·66	5·72	0·02	—	33·2
67—70	1005	422	537	46	42·0	53·4	4·6	2830·5	3782·5	—	952·0	6·71	7·04	—	0·95	44·5
71—74	65	29	35	1	44·6	53·9	1·5	206·0	277·5	—	71·5	7·10	7·93	—	1·10	56·9
Total	4000	1862	1951	187	4·65	48·8	4·7	11015·5	11740·5	—	325·0	5·92	6·02	—	0·18	35·3

Appendix X.—Experiments made at Wakefield Gaol, 1861.

Two Tailors.—Light labour.

Date.	Daily Ingesta.									Daily Egesta.													Weight of body, in lbs. and ozs. avoirdupois.			Urea to 1 lb. of body-weight.
	Bread.			Chloride of Sodium besides that in the bread.			Water (not in food).			Fæces. Quantity.		Fæces. Nitrogen.		Urine. Quantity.			Urea.		Nitrogen, daily.		Chloride of Sodium.					
	No. 182.	No. 184	Aver-age.	No. 182	No. 184.	Average.	No. 182.	No. 184	Aver-age	No. 182.	No. 184	Per cent., both.	Total daily quan-tity.	No. 182.	No. 184.	Aver-age.	Per fl. oz. of urine	Total daily.	Urine.	Total in urine and fæces	In each fl. oz of urine.	Total daily in urine	No. 182.	No. 184.	Aver-age.	
1861.	grs.	grs	grs	grs	grs.	grs.	fl oz.	fl oz	fl oz.	oz.	oz.	grs.	grs	fl. oz	fl. oz.	fl oz	grs.	grs.	grs.	grs	grs	grs	124 13	117 9¾	121 35	grs.
June 28	10,913	10,898	10,906	194	49	121·5	18	10½	14¼	6 88	9·66	...	...	44·4	56·6	50 5	14 4	707	330 4		3 0	151 5	125 2¾	117 8	121 35	5 82
„ 29	10,849	10,338	10,594	141½	75½	108 5	16	17	16½	4·33	7 19	...	...	59·17	39·04	49 1	14·76	725	338 8	...	3 6	176 7	125 2	118	121·28	5·91
„ 30 Sunday	10,791	11,192	10,992	201½	45½	123 5	15	17	16	5·6	10 85	·789	28·5	35·4	43·45	39·45	14·7	580	271·0	299·5	3·0	118 3	125 11½	118 11¼	122 21	4·74
July 1	10,908	10,748	10,828	187½	87½	137 5	4	10	7	7 53	11·41	·71	24·13	40·0	50·67	45 38	12 30	569	265 8	295 23	2 7	122 4	125 10¾	118 5¾	122·0	4 66
„ 2	10,988	10,727	10,858	190	86	138	29	31	30	5·55	5·35	1 03	24 51	31 7	43 3	37 5	13 36	501	234·1	258 61	3·0	112 5	125 8½	119 0	122 26	4 09
„ 3	12 612	10,506	11 556	192½	92	142 2	10	5	7½	4·83	9 64	·88	27·59	32·4	38·5	35·45	13·71	456	213·0	240·59	2·7	95·7	125 13¾	118 13¾	122 36	3 72
„ 4	9,652	10,145	9,899	178	102½	140 2	9	3½	5¼	7·09	10 28	·77	29 27	34·9	41 0	37 95	11 44	547	255 6	284 87	3 6	136 6	126 3¼	118 10¾	122 13	4·46
„ 5	10,430	10,446	10,438	224	115	169 5	8	7½	7¾	5·55	5·06	1·08	25·1	35·7	40 0	37 85	15 64	592	278 5	303 6	3·6	135 0	126 2¼	119 7	122 8	4 82
„ 6	4,275	10,095	10,685	202	143½	172 7	17½	8	12¾	6 21	10 82	·79	29·15	49·0	47·5	48 25	13 83	668	312 1	341 55	2 7	130 27	125 15½	118 9½	122 27	5 46
„ 7 Sunday	10,854	10,343	10,599	190½	42½	166 5	9½	11	10¼	5 66	5 9	·98	24·77	33·3	42·5	37 9	14 4	546	255 5	280 27	4·0	151·6	126 4½	119 3½	122 75	4 44
July 8	10,206	9,187	9,697	192	39	116	5	9	7	4 83	10 1	·93	30 48	38·4	39 0	38·7	17·04	660	307·4	337 88	4·0	154 8	126 0	119 1¼	122 53	5·38
„ 9	9,830	11,331	10,581	231	41½	136 2	15	7	11	5·09	4 53	1 16	24 42	33 8	41·5	37 65	18 8	708	376 6	401 02	4 0	150 6	125 11½	118 9	122 14	5·79
„ 10	9,893	11,256	10,575	217	40	128·5	11½	9½	11½	5·53	5·78	1·14	28·23	39·3	40·0	39·65	16 4	650	303 7	331·93	4 0	158·6	125 13½	119 5¼	122 6	5·3

Two Matting Weavers.—Heavy labour.

Date.	Daily Ingesta.									Daily Egesta.													Weight of body, in lbs. and ozs. avoirdupois.			Urea to 1 lb. of body-weight.
	Bread.			Chloride of Sodium besides that in the bread.			Water (not in food).			Fæces. Quantity.		Fæces. Nitrogen.		Urine. Quantity.			Urea.		Nitrogen, daily.		Chloride of Sodium.					
	No. 7.	No. 39.	Aver-age.	No. 7.	No. 39.	Average.	No. 7.	No. 39.	Aver-age.	No. 7.	No. 39.	Per cent., both.	Total daily quan-tity.	No. 7.	No. 39.	Aver-age.	Per fl. oz. of urine.	Total daily.	Urine.	Total in urine and fæces.	In each fl. oz. of urine.	Total daily in urine.	No. 7.	No. 39.	Aver-age.	
1861.	grs	grs	grs.	grs	grs	grs.	fl oz.	fl oz	fl. oz.	oz	oz.	grs.	grs.	fl. oz.	fl. oz.	fl oz	grs.	grs	grs.	grs.	grs	grs.	146 8½	147 3½	146 87	grs.
June 28	12 958	12,848	12 918	86½	38½	62 5	31½	60	45¾	9 04	8 48	...	...	36 8	62·3	49·55	13·71	671	313·4	...	2 4	118 9	146 10	146 6¾	146 51	4 55
„ 29	14,543	14,664	14,604	88	39½	63·7	40	61	50½	15·51	5·96	...	...	42 7	61·15	51 92	13 8	717	335 0	...	2·7	140 1	146 3¼	146 4¼	146 25	4 9
„ 30	11,526	14,305	12,917	78½	None	......	14	16	15	6 63	5·88	1·03	26·41	41·06	48·9	44 98	15·36	691	322 9	349·31	2·4	107·9	147 6½	146 11	147·1	4·7
July 1	13,607	13,475	13,541	69	37½	53 2	40	17½	28¾	2 03	10 33	1·24	34·16	53·8	40·	46 9	14·76	692	323 3	357 16	3 3	151 7	147 9¾	146 11	147·15	4·7
„ 2	13,127	12,407	12,767	73	37	55	40	29	34½	10 11	8 52	1·15	46 26	53·9	35 7	45 8	13·89	637	297 3	343 56	3 9	178·6	146 10½	146 13¼	146 75	4·31
„ 3	13,629	13,758	13,694	88½	42	65 2	29	40	34½	8 0	13 0	1 10	50 71	29·4	42·9	46 15	15 42	558	262 6	313 31	3 6	166·8	147 0¾	146 11	146·9	3 62
„ 4	13,314	13,412	13,363	105	40½	72 7	40	40	40	5 35	9·23	1 04	34 66	45 5	45·	45 25	15 9	710	331·8	366·46	3 6	162 9	147 5½	146 14	147 11	4·83
„ 5	12,829	14,588	13,709	86	41	63 5	40	40	40	4·32	7 94	0 97	26 01	55	44·	49 5	15 45	765	357 3	383 31	3 3	163 3	147 2	146 0¾	146 58	5·21
„ 6	12,260	14,050	13,155	93	50	71 5	40	29	34½	10 94	8 64	1·35	57·8	74·	40·5	57·25	13 53	775	262 1	519 9	2 7	154 5	146 4	146 10	146 43	5 29
„ 7	13,254	13,340	13,297	82	25½	58 7	30½	14	22¼	1 72	14·4	1·00	35 28	48·5	37·5	43·	15 87	683	319·1	354 38	2 7	116 1	148 3½	147 12¼	147 98	4 61
„ 8	12,613	12,687	12,650	85	54	74 5	33	40	36½	10 7	5 28	1·31	45 81	49·	44·	46·5	15 2	707	330 3	376 11	3 6	167 4	146 14½	147 12	147·32	4·8
„ 9	12,943	13,753	13,348	88	76½	82 2	50	10	45	6·74	12 84	1 05	45 03	46·	46·	46·	16·0	736	343 9	388·93	3·6	165 6	144 15½	147 11¼	146 34	5·02
„ 10	13,232	13,010	13,121	80	66	73	40	29	34½	10 48	10·45	1·05	48 1	42·	46·5	44·25	17·84	790	369 1	417·2	3·6	159 3	144 9¾	147 2¼	146·36	5·39

APPENDIX IX.—Showing the relation of Weight to Season.

Month.	No. of prisoners weighed.	Number of Prisoners			Percentage of Prisoners			Number of Pounds		Net		Average			
		Gaining weight.	Losing weight.	Station-ary.	Gaining weight.	Losing weight.	Station-ary.	Gained.	Lost.	Gain.	Loss.	Gain per prisoner gaining.	Loss per prisoner losing.	Gain per prisoner weighed.	Loss per prisoner weighed.
January	3,879	1,645	1,918	316	42·4	49·4	8·2	3723·5	4274·0	—	550·5	2·26	2·25	—	0·14
February	3,747	1,561	1,808	378	41·6	48·3	10·1	3140·0	4051·0	—	911·0	2·01	2·24	—	0·24
March............	3,632	1,058	2,272	302	29·1	62·6	8·3	1918·5	5372·5	—	3454·0	1·81	2·37	—	0·95
April	3,793	1,733	1,704	356	45·7	44·9	9·4	3710·0	3578·5	131·5	—	2·14	2·10	0·03	—
May..............	3,673	1,627	1,694	352	44·3	46·1	9·6	3825·5	3795·0	30·5	—	2·35	2·24	0·01	—
June.............	3,731	1,918	1,455	358	51·4	39·0	9·6	5322·0	3381·0	1941·0	—	2·77	2·32	0·52	—
July	3,511	1,622	1,546	343	46·2	44·0	9·8	3426·5	3135·5	291·0	—	2·11	2·04	0·08	—
August	3,446	1,903	1,211	332	55·2	35·1	9·7	4879·5	2483·0	2396·5	—	2·56	2·05	0·70	—
September.......	3,684	1,474	1,881	329	40·0	51·1	8·9	3303·0	4080·5	—	777·5	2·24	2·17	—	0·21
October	3,734	1,624	1,768	342	43·5	47·3	9·2	3515·0	3905·0	—	390·0	2·16	2·21	—	0·10
November	3,621	1,636	1,613	372	45·2	44·5	10·3	3345·5	3329·5	16·0	—	2·04	2·06	0·004	—
December	3,553	1,519	1,682	352	42·8	47·3	9·9	3237·0	3356·0	—	119·0	2·13	1·99	—	0·03
First quarter....	11,258	4,264	5,998	996	37·9	53·3	8·8	8782·0	13697·5	—	4915·5	2·06	2·29	—	0·44
Second quarter	11,197	5,278	4,853	1066	47·1	43·4	9·5	12857·5	10754·5	2103·0	—	2·44	2·22	0·19	—
Third quarter...	10,641	4,999	4,638	1004	47·0	43·6	9·4	11609·0	9699·0	1910·0	—	2·32	3·09	0·17	—
Fourth quarter	10,908	4,779	5,063	1066	43·8	46·4	9·8	10097·5	10590·5	—	493·0	2·11	2·09	—	0·05
Winter months	22,166	9,043	11,061	2062	40·8	49·9	9·3	18879·5	24288·0	—	5408·5	2·09	2·90	—	0·24
Summer months	21,838	10,277	9,491	2070	47·0	43·5	9·5	24466·5	20453·5	4013·0	—	2·38	2·16	0·18	—
Whole year	44,004	19,320	20,552	4132	43·9	46·7	9·4	43346·0	44741·5	—	1395·5	2·24	2·18	—	0·03

Freight as affected by Differences in the Dynamic Properties of Steam-ships. By CHARLES ATHERTON, *Chief Engineer, H.M. Dockyard, Woolwich.*

THE national importance of steam shipping is a theme which demands no demonstration; and any attempt to originate, promulgate, and popularize inquiry into the comparatively economic capabilities of the steam-ship as devoted to the international conveyance and interchange of the products of nature and of manufacturing art, irrespective of its application as an engine of war, is a task which requires no laboured introduction in support of its being favourably received for consideration by an association devoted to the advancement of science.

The former papers on 'Tonnage,' 'Steam-Ship Capability,' and 'Mercantile Steam Transport Economy,' which the author of this further communication has been permitted to present to the British Association, and which appear in the volumes of its 'Transactions' for the years 1856, 1857, and 1859, were devoted to an exposition of the technicalities of the subject as respects the mutual quantitative relations which displacement, speed, power, and coal hold to each other in the construction and equipment of steam-ships with a view to the realization of definite steaming results. So far, therefore, these investigations have had reference to the constructive equipment of steam-ships; but the course of inquiry now submitted for consideration is intended to be a practical exposition of the extent to which the expense per ton weight of cargo conveyed is affected by the various conditions of size of ship, dynamic quality of hull with reference to type of form, weight of hull with reference to its build, the economic properties of the engines with reference to the consumption of fuel, and the steaming speed at which the service is required to be performed, all which circumstances, respectively and in their combinations, affect the economic capabilities of steam-ships for the conveyance of mercantile cargo, and consequently freights charged, to an extent not publicly known because hitherto not specially inquired into nor promulgated by the press, and which in the distinctive details above set forth do not appear to have been duly appreciated even by the parties most deeply concerned in the mercantile control and prosecution of steam-shipping affairs. The aggregate expenses incidental to the prosecution of steam transport service must generally regulate the average rates of freight at which goods are conveyed; and, seeing to what an extent the ultimate cost of manufactured goods is dependent on the cost of transport, often repeated, as freight charges generally are in the various stages of transition of material from the raw to its manufactured condition and its ultimate consumption as a manufactured article, it becomes evident that this investigation especially concerns the manufacturing interests of the country. Economy of price inducing quantity of consumption, is the characteristic feature of the manufacturing enterprise of the present day; and it is the absolute cost of goods which affects consumption, irrespectively of the various causes in detail by which the cost may have been enhanced. Under these circumstances, it is remarkable to what extent the manufacturing interests, though keenly alive to legislative imposts, whether foreign or domestic, affecting the cost of goods, and sensitively jealous of legislative interference in the control of labour, as affecting the cost of manufacture, pass wholly unheeded deficiencies and imperfections in the practical control of shipping with reference to freight charges, though equally affecting the ultimate price of manufactures. Such incongruity demonstrates the necessity for popular exposition and inquiry into the various circumstances and combinations of circumstances which directly affect the expenses incidental to the conveyance of merchandise by steam-ships, and by which the rates of freight are in the aggregate necessarily regulated. Freight, therefore, is the text of the following discourse, to which attention is directed under the various aspects of steam-ship construction and management, by which freight charge is affected, and which may be classified under ten heads or sections, as follow:—

SECTION A.—Freight, as affected by variations of the size of the ship by which the service is performed.

B.—Freight, as affected by variations in the constructive type of form of the hull.

C.—Freight, as affected by variations in the working economy of the engines, with reference to the consumption of coal.

D.—Freight as affected by variations in the constructive weight of the hull, with reference to its load displacement.

E.—Freight, as affected by variations in the constructive type of form combined with variations in the working economy of the engines.

F.—Freight, as affected by variations in the size of ship combined with variations in the constructive type of form and in the working economy of the engines.

G.—Freight, as affected by variations of the steaming speed at which it is required that the service shall be performed.

H.—Freight, as affected by variations of the size of ship combined with variations of speed.

I.—Freight, as affected by variations of the speed combined with variations of the working economy of the engines.

K.—Freight, as affected by variations of the speed combined with variations in the type of form, working economy of the engines, and weight of hull.

It will be observed that it is not proposed to determine the actual amount of prime-cost expenses incidental to the prosecution of steam-ship enterprise, by which the scale of freight charge may be chiefly regulated, but it is proposed to demonstrate, with reference to a specified unit of performance, the ratio or comparative scale of cost, in which the prime-cost expenses incidental to the conveyance of cargo per ton weight of goods conveyed on a given passage is, *cæteris paribus*, affected by each of the various circumstances or conditions set forth under the ten different heads above referred to.

The fundamental consideration on which it is proposed to base this investigation is this, that, within moderate limits of variation, the investment incidental to the fitting-out of steam-ships for commercial transport service is approximately proportional to the quantity of shipping as measured by the constructors' load displacement of the ships, and the amount of working-power employed as measured by the indicated horse-power, also that the interest on investment, upholding of stock, and all other annual expenses incidental to the working of steam-ships, such as coals, stores, and wages, harbour dues, insurance, and pilotage, are approximately proportional to such investment; and further, as the mercantile service of steam-ships employed on a given station generally requires that their passages shall be periodical, it is assumed in the following calculations that the number of passages made annually by each ship is the same in all the different vessels assumed to be employed on the same service and brought into comparison with each other.

It is particularly to be observed that these calculations and deductions of comparative freight charges are not of general application to different services, but have reference only to the special service which, as an example of the system of calculation for any service, has been adopted as the unit of performance, namely, the performance of a ship of 5000 tons displacement, employed on a passage of 3000 nautical miles and steaming at ten knots per hour,—the coefficient of performance, by the formula $\frac{V^3 D^{\frac{2}{3}}}{\text{Ind. h.p.}}=C$, being $C=250$, and the consumption of coal being at the rate of 2lbs. per indicated horse-power per hour, which data have been assumed as the base of the following tabular statement, consisting of 21 columns, the purport of which is as follows:—

Column 1st.—Reference to divisions or sections of the subject under consideration.

2nd and 21st.—Designations of the vessels referred to in the various sections.

3rd.—Size of the ship as determined by displacement at the draft to which it is intended by the constructor that the ship shall be loaded.

4th.—Steaming speed at which the vessel is required to perform the passage.

5th.—Coefficient of dynamic performance of the vessel by the formula $\frac{V^3 D^{\frac{2}{3}}}{\text{Ind. h.p}}=C$.

6th.—Consumption of coal per indicated horse-power per hour expressed in lbs.

7th.—Coefficient of dynamic duty with reference to coal consumed by formula $\frac{V^3 D^{\frac{2}{3}}}{W}$ W being the average consumption of coal expressed in cwts. per hour.

8th.—Power required to propel the vessel at the required speed expressed in indicated horse-power and calculated by the formula, indicated horse-power $=\frac{V^3 D^{\frac{2}{3}}}{C}$

9th.—Length of passage to be performed by the ship without re-coaling expressed in nautical miles.

10th.—Weight of hull, including all equipment complete for sea (exclusive of engines, coal, and cargo), taken at 40 per cent. of the load displacement.

11th.—Weight of engines and boilers in working order, including all equipment for sea, taken at the rate of 5 cwt. per indicated horse-power.

12th.—Weight of coal required for the passage, calculated on the foregoing data.

13th.—Cargo, as determined by the load displacement less the weight of hull, engines, and coal.

14th.—Investment in the hull of the ship, including rigging, furnishing, and all other equipment complete for sea, taken at £50 per ton weight of hull.

15th.—Investment in the engines, including spare gear and all equipment for sea, taken at £15 per indicated horse-power.

16th.—Total investment in hull and engines.

17th.—Comparative rates of freight or ratios of cost expenses per ton of cargo, being proportional to the investment divided by the tons weight of cargo conveyed.

18th.—Ratios of cost expenses per ton of cargo, with reference to that incurred by ship A, taken as the unit of performance, and which is expressed by the number 100.

19th.—Ratios of cost expenses per ton of cargo with reference to the cost incurred by ship A, taken as the unit of performance, and which is expressed by £1 per ton.

20th.—Comparative freight on 100,000 tons of goods, assuming the freight by ship A to be at the rate of £1 per ton of goods conveyed.

21st.—Designations of vessels referred to in the sections.

The table (next page) may be interpreted as follows:—

Section A.—Freight, as affected (*cæteris paribus*) by variations of the size of ship.

By reference to the table (next page) it will be observed that as the ship's size (column 3) is reduced from 5000 tons displacement to 4000 tons, the expenses per ton of cargo (column 17) become increased in the ratio of 49 to 51, that is, in the ratio of 100 to 104 (column 18), showing an increase of 4 per cent.; or, expressed in money, assuming £1 per ton to be the rate of freight by ship A, of 5000 tons displacement, the rate by ship A_1, of 4000 tons displacement will be £1 0*s.* 10*d.*, and by following the table it appears that the rate of freight by ship A_2, of 3000 tons, will, as compared with ship A, of 5000, be increased 8 per cent., amounting to £1 1*s.* 8*d.* per ton.

The comparative freight charges on 100,000 tons of goods (column 20) by the vessels A, A_1, A_2, respectively would be £100,000, £104,000 and £108,000.

Thus, in a merely mechanical point of view, and irrespectively of various mercantile and nautical considerations which may limit the size of ships, we see the benefit of performing goods transport service by large vessels in preference to small ones, provided that adequate cargo be always obtained and that no delay be thereby incurred. But it is to be observed that if the 5000-tons ship A, instead of being loaded with its full cargo of 2395 tons, be loaded only with the quantity of cargo (1878 tons) that could be carried by the 4000-tons ship, A_2, the freight expenses per ton of cargo would, in this case, be enhanced in the proportion of 63 to 49, that is, in the proportion of 128 to 100, or 28 per cent., or, expressed in money, in the proportion of £1 4*s.* 10*d.* to £1, the same being a higher rate by 24 per cent. than the freight charge at which the 4000-tons ship, A_1, would perform the service. By pursuing the calculations from the data adduced by the table, it will be found that the economic advantage of the 5000-tons ship, A, as compared with the 4000-tons ship, A_1, will be entirely sacrificed if its cargo be reduced from 2395 tons to 2305 tons, or be only 90 tons, or $3\frac{3}{4}$ per cent. deficient of its full load. Also, as compared with the ship A_2, of 3000 tons, the advantage of the 5000-tons ship A will be lost if its cargo be reduced from 2395 tons to 2218, or be only 117 tons deficient of its full load.

Hence it appears that the superior economic capabilities of large ships in a mechanical point of view for the conveyance of goods may, in a mercantile point of view, be very soon sacrificed by mismanagement in assigning larger vessels for the discharge of mercantile service than is demanded by the trade, notwithstanding the economic superiority of large ships when promptly and fully loaded.

Section B.—Freight, as affected (*cæteris paribus*) by variations in the constructive type of form of the hull.

The relative constructive efficiency of mercantile ships in a purely dynamic point of view, as respects type of form (irrespectively of materials and workmanship), is now generally recognized as being determined by their coefficients (C) of dynamic performance, as deduced from actual trial of the ships, and calculated by the following formula $\frac{V^3 D^{\frac{2}{3}}}{\text{Ind. h.p.}} = C$, which may be expressed as follows:—

1	2	3	4	5	6	7	8	9	10	11
									Weight of	
Reference.	Designation of Vessels.	Constructor's load displacement.	Steaming speed per hour.	Coefficient of performance.	Coal per Ind. h. p. per hour.	Coefficient of dynamic duty.	Power.	Passage.	Hull and its equipment.	Engines and their equipment.
Section.		Tons.	Knots.	$\frac{V^3 D^{\frac{2}{3}}}{\text{Ind.h.p.}}$	Lbs.	$\frac{V^3 D^{\frac{2}{3}}}{W.}$	Ind. h. p.	N. miles.	Tons.	Tons.
	A	5000	10	250	2	14,000	1170	3000	2000	292
A	A_1	4000	10	250	2	14,000	1008	3000	1600	252
	A_2	3000	10	250	2	14,000	832	3000	1200	208
	A	5000	10	250	2	14,000	1170	3000	2000	292
B	B_1	5000	10	200	2	11,200	1462	3000	2000	365
	B_2	5000	10	150	2	8,400	1950	3000	2000	487
	A	5000	10	250	2	14,000	1170	3000	2000	292
C	C_1	5000	10	250	3	9,333	1170	3000	2000	292
	C_2	5000	10	250	4	7,000	1170	3000	2000	292
	A	5000	10	250	2	14,000	1170	3000	2000	292
D	D_1	5000	10	250	2	14,000	1170	3000	2500	292
	D_2	5000	10	250	2	14,000	1170	3000	3000	292
	A	5000	10	250	2	14,000	1170	3000	2000	292
E	E_1	5000	10	200	3	7,467	1462	3000	2000	365
	E_2	5000	10	150	4	4,200	1950	3000	2000	484
	A	5000	10	250	2	14,000	1170	3000	2000	292
F	F_1	4000	10	200	3	7,467	1260	3000	1600	315
	F_2	3000	10	150	4	4,200	1386	3000	1200	346
	A	5000	10	250	2	14,000	1170	3000	2000	292
G	G_1	5000	12	250	2	14,000	2021	3000	2000	505
	G_2	5000	14	250	2	14,000	3209	3000	2000	802
	A	5000	10	250	2	14,000	1170	3000	2000	292
H	H_1	4000	12	250	2	14,000	1702	3000	1600	425
	H_2	3000	14	250	2	14,000	2283	3000	1200	571
	A	5000	10	250	2	14,000	1170	3000	2000	292
I	I_1	5000	12	250	3	9,333	2021	3000	2000	505
	I_2	5000	14	250	4	7,000	3209	3000	2000	802
	A	5000	10	250	2	14,000	1170	3000	2000	292
K	K_1	5000	12	225	3	8,333	2245	3000	2250	561
	K_2	5000	14	200	4	5,600	4012	3000	2500	1003

12	13	14	15	16	17	18	19	20	21
Weight of		Investment.							
Coal for the passage.	Cargo.	Hull at £50 per ton weight.	Engines at £15 per Ind. h. p.	Total.	Comparative expenses per ton of cargo.	Ratios, with reference to freight by ship A, taken at 100.	Rates, with reference to freight by ship A, at £1 per ton weight.	Comparative freight on 100,000 tons.	Designation of Vessels.
Tons.	Tons.	£	£	£	Investment / Cargo.	Ratios.	£ s. d.	£	
313	2395	100,000	17,550	117,550	49	100	1 0 0	100,000	A
270	1878	80,000	15,120	95,120	51	104	1 0 10	104,000	A_1
223	1369	60,000	12,480	72,480	53	108	1 1 8	108,000	A_2
313	2395	100,000	17,550	117,550	49	100	1 0 0	100,000	A
392	2243	100,000	21,930	121,930	54	110	1 2 0	110,000	B_1
522	1991	100,000	29,250	129,250	65	132	1 6 5	132,000	B_2
313	2395	100,000	17,550	117,550	49	100	1 0 0	100,000	A
470	2238	100,000	17,550	117,550	52	106	1 1 2	106,000	C_1
627	2081	100,000	17,550	117,550	56	114	1 2 10	114,000	C_2
313	2395	100,000	17,550	117,550	49	100	1 0 0	100,000	A
313	1895	125,000	17,550	142,550	75	153	1 10 7	153,000	D_1
313	1395	150,000	17,550	167,550	120	245	2 9 0	245,000	D_2
313	2395	100,000	17,550	117,550	49	100	1 0 0	100,000	A
588	2047	100,000	21,930	121,930	59	120	1 4 0	120,000	E_1
1044	1472	100,000	29,250	129,250	88	179	1 15 10	179,000	E_2
313	2395	100,000	17,550	117,550	49	100	1 0 0	100,000	A
506	1579	80,000	18,900	98,900	62	126	1 5 2	126,000	F_1
742	712	60,000	20,790	80,790	113	230	2 6 0	230,000	F_2
313	2395	100,000	17,550	117,550	49	100	1 0 0	100,000	A
451	2044	100,000	30,315	130,315	64	131	1 6 2	131,000	G_1
614	1584	100,000	48,135	148,135	93	182	1 16 5	182,000	G_2
313	2395	100,000	17,550	117,550	49	100	1 0 0	100,000	A
380	1595	80,000	25,530	105,530	66	134	1 6 10	134,000	H_1
437	792	60,000	34,245	94,245	119	243	2 8 7	243,000	H_2
313	2395	100,000	17,550	117,550	49	100	1 0 0	100,000	A
677	1818	100,000	30,315	130,315	72	147	1 9 5	147,000	I_1
1228	970	100,000	48,135	148,135	152	310	3 2 0	310,000	I_2
313	2395	100,000	17,550	117,550	49	100	1 0 0	100,000	A
751	1438	112,500	33,675	146,175	102	208	2 1 8	208,000	K_1
1535	0	...	...	...	...	...	...	...	K_2

Multiply the cube of the speed (V^3) by the cube root of the square of the displacement ($D^{\frac{2}{3}}$), and divide the product by the indicated horse-power (Ind. h. p.); the quotient will be the coefficient (C) of dynamic performance.

To enter upon the various uses to which this formula is applied would be irrelevant to the matter now under consideration. Suffice it to say that the numeral co-efficient obtained as above set forth affords practically a means by which the mutual relations of displacement, power, and speed of a steam-ship of given type of form, and of which the coefficient is known, may (*cæteris paribus*) be deduced, and it affords a criterion indicating, whatever be the size of the ship, the constructive adaptation of its type of form for mechanical propulsion, as compared with other types of form tested by the same rule—the condition of the vessels as respects cleanness of immersed surface, stability, and other essential properties, being assumed to be the same; and we now proceed to show to what extent, under given conditions, freight per ton of goods conveyed is affected by variations of type of form, as represented by variations of the coefficient of performance.

By reference to the table (Section B), it will be observed that as the co-efficient of dynamic performance is reduced from 250 to 150, the expenses become increased in the ratio of 100 to 132, or 32 per cent., or, assuming the freight by ship A, of which the coefficient of dynamic performance is 250, to be at the rate of £1 per ton of cargo, the charge by ship B_1, of the same size, but of which the coefficient is 200, will be £1 2*s*., being an increase of 10 per cent.; and the charge by ship B_2, of the same size, but of which the coefficient is 150, will be £1 6*s*. 5*d*., being an increase of 32 per cent., as compared with the rate of freight by ship A, of which the coefficient is 250.

The comparative freight charges on 100,000 tons of goods by the vessels A, B_1, B_2, respectively, would be £100,000, £110,000, and £132,000.

Seeing, therefore, that variations of the type of form, as indicated by variations of the coefficient of dynamic performance, even within the limits of 250 and 150, which are of ordinary occurrence in steam-shipping, affect the expenses incidental to the conveyance of mercantile cargo, under the conditions referred to, to the extent of 32 per cent., the coefficient of dynamic performance which a ship may be capable of realizing, being thus (*cæteris paribus*) a criterion of the economic working of the ship with reference to power, becomes a highly important matter for directorial consideration in the purchasing or disposal of steam-ships.

Section C.—Freight as affected (*cæteris paribus*) by variations in the working economy of the engines with reference to coal.

The relative working economy of marine engines as respects the consumption of coal per indicated horse-power per hour is evidently an important element for consideration as affecting freight,—to illustrate which, it has been assumed that variations in mercantile practice extend from 2 lbs. per indicated horse-power per hour to 4 lbs. The consumption of so little as 2 lbs. per indicated horse-power per hour is not usually attained, but being now admitted to have been achieved, and such having become a matter of contract stipulation, it may be looked forward to as the probable future consumption on board ship generally, although the ordinary consumption of existing steamers cannot at the present time be rated at less than 4lbs. per indicated horse-power per hour.

By reference to the table (Section C), it appears that, under the special conditions of the service under consideration (namely vessels of 5000 tons displacement employed on a passage of 3000 nautical miles, and steaming at the speed of 10 knots an hour), by increasing the consumption of coal from 2 lbs. to 4 lbs. per indicated horse-power per hour, the expense per ton of goods conveyed becomes increased in the proportion of 49 to 56, that is, in the proportion of 100 to 114, being an increase of 14 per cent., or, assuming the freight by the standard ship A, consuming 2 lbs. of coal per indicated horse-power per hour, to be at the rate of £1 per ton of cargo conveyed, the rate of freight by ship C_1, consuming 3 lbs. per indicated horse-power per hour, will be £1 1*s.* 2*d.*, being an increase of 6 per cent., and the rate of freight by ship C_2, consuming 4 lbs. per indicated horse-power per hour, will be £1 2*s.* 10*d.*, being an increase of 14 per cent. per ton of goods conveyed under the conditions referred to.

The comparative freight charges on 100,000 tons of goods by the vessels A, C_1, C_2, respectively would be £100,000, £106,000, and £114,000.

SECTION D.—Freight charge as affected (*cæteris paribus*) by variations in the constructive weight of hull with reference to the size of the ship as determined by the load displacement.

To illustrate this matter it has been assumed that the weight of hull, including the whole equipment complete for sea (exclusive of engines, coal, and cargo) may vary from 40 per cent. of the load displacement to 60 per cent., under which limitations, by reference to table (Section D), it appears that, under the special conditions of the service under consideration, by increasing the weight of hull from 40 per cent. of its displacement to 60 per cent., and assuming the cost of the hull to be in proportion to its weight of materials, the expenses or freight charge per ton of cargo conveyed become increased in the proportion of 49 to 120, that is, in the proportion of 100 to 245, being an increase of 140 per cent., or, assuming the freight charge by the standard ship A, of which the weight of hull is 40 per cent. of the load displacement (2000 tons) to be at the rate of £1 per ton of goods conveyed, the rate of freight by ship D_1, of which the weight of hull is 50 per cent. of the load displacement (2500 tons), will be £1 10*s.* 7*d.* per ton, being an increase of 53 per cent., and by ship D_2, of which the weight of hull is 60 per cent. of the load displacement (3000 tons), the rate of freight becomes £2 9*s.* per ton, being an increase of 145 per cent. per ton of goods conveyed under the conditions referred to.

The comparative freight charges on 100,000 tons of goods by the vessels A, D_1, D_2, respectively, would be £100,000, £153,000, and £245,000.

Hence, in the construction of steam-ships we see the importance of quality of material and excellence of fastening as a means of reducing weight, and the disadvantage that attends heavy-built ships, such as war-steamers, for discharging mercantile service. Hence also we see the deficient steaming endurance or limited armament of high-speed armoured ships unless built of enormous size, as measured by their load displacement, and the disadvantage of types of form which require the aid of ballast to insure stability.

SECTION E.—Freight is affected (*cæteris paribus*) by variations in the constructive type of form combined with variations in the working economy of the engines.

By reference to the Table (Section E), it appears, under the special conditions of the service under consideration, that by an inferior type of form, as indicated by the coefficient of performance being reduced from 250 to 150, combined with an inferior construction of engines, as indicated by the consumption of fuel being increased from 2 lbs. to 4 lbs. per indicated horse-power per hour, thereby reducing the coefficient of dynamic duty (column 7) from 14,000 to 4200, the expense or freight charge per ton of goods conveyed becomes increased in the ratio of 100 to 179, being an increase of 79 per cent.; or, assuming the freight charge by the standard ship A, of which the coefficient of performance is 250 and rate of consumption 2 lbs. per indicated horse-power per hour (giving a coefficient of dynamic duty 14,000), to be at the rate of £1 per ton of goods conveyed, the rate of freight by ship E_1, of which the coefficient of performance is 200, and consumption of coals 3 lbs. per indicated horse-power per hour (coefficient of dynamic duty 7467) becomes £1 4*s.* per ton, being an increase of 20 per cent., and by ship E_2, of which the coefficient of performance is 150, and the consumption of coal at the rate of 4 lbs. per indicated horse-power per hour (coefficient of dynamic duty 4200), the rate of freight becomes £1 15*s.* 10*d.*, being an increase of 79 per cent. per ton of goods conveyed under the conditions referred to. The comparative freight charges on 100,000 tons of goods by the vessels A, E_1, E_2, respectively, would be £100,000, £120,000, and £179,000.

Hence, in the control of steam-shipping, we see the importance of the coefficient of dynamic duty (column 7), as indicating the economic efficiency of the ship in a mercantile point of view, with reference to the merits of her hull and engine construction being made a subject of contract stipulation.

SECTION F.—Freight as affected (*cæteris paribus*) by variations in the size of the ship combined with variations in the constructive type of form and in the working economy of the engines.

By reference to the Table (Section F), it appears, under the special conditions of service under consideration, that by the size of the ship being reduced from 5000 tons displacement to 3000 tons displacement, combined with an inferior type of form, as indicated by the coefficient of performance being reduced from 250 to 150, and an inferior construction of engine, as indicated by the consumption of coals being increased from 2 lbs. to 4 lbs. per indicated horse-power per hour, the expense or freight charge per ton of goods conveyed becomes increased in the ratio of 49 to 113, that is, in the ratio of 100 to 230, being an increase of 130 per cent.; or, assuming the freight by the standard ship A, of 5000 tons, of which the coefficient of performance is 250, and the consumption of coal at the rate of 2 lbs. per indicated horse-power per hour, to be at the rate of £1 per ton of goods conveyed, the rate of freight by ship F_1, of 4000 tons, of which the coefficient of performance is 200 and the consumption of coal at the rate of 3 lbs. per indicated horse-power per hour, will be £1 5*s.* 2*d.*, being an increase of 26 per cent., and by ship F_2, of 3000 tons displacement, of which the coefficient of performance is 150 and the consumption of coal at the rate of 4 lbs. per indicated horse-power per hour, the rate of freight becomes £2 6*s.*, being an increase of 130 per cent. per ton of goods conveyed under the conditions referred to.

The comparative freight charges on 100,000 tons of goods by the vessels A, F_1, F_2, respectively, would be £100,000, £126,000, and £230,000.

Hence also we observe by comparison of ships E_2 and F_2, how important becomes the question of magnitude when ships of inferior dynamic duty are employed on a given service, the comparative freight charges on 100,000 tons of goods conveyed by the vessels E_2 and F_2, on the service referred to, being £179,000 and £230,000, being an increase of 28 per cent. solely in consequence of the magnitude of the ship being reduced from 5000 tons displacement to 3000 tons, the coefficient of dynamic duty (4200) being in both cases the same.

SECTION G.—Freight as affected (*cæteris paribus*) by variations of the steaming speed at which it is required that the service shall be performed.

It is proposed to illustrate this most important elemental consideration by reference to rates of speed within the range of present practice, namely, from 10 to 14 knots per hour.

By reference to the Table (Section G), it appears that, under the special conditions of the service under consideration, by increasing the speed from 10 to 12 knots per hour, the expense or required rate of freight per ton of goods conveyed becomes increased in the ratio of 49 to 64, that is, in the ratio of 100 to 131, being an increase of 31 per cent.; and by increasing the speed from 10 to 14 knots, the expense, or required rate of freight per ton of goods, becomes increased in the ratio of 49 to 93, that is, in the ratio of 100 to 182, being an increase of 82 per cent. Hence, assuming the freight by the standard ship A, of 5000 tons, making a passage of 3000 nautical miles at 10 knots per hour, to be at the rate of £1 per ton weight of goods conveyed, the rate of freight by ship G_1, steaming at 12 knots per hour, will be required to be £1 6*s.* 2*d.* per ton weight of goods conveyed, and the rate of freight by ship G_2, steaming at 14 knots per hour, will be required to be £1 16*s.* 5*d.* per ton of goods conveyed. The comparative freight charges on 100,000 tons of goods, by the vessels A, G_1, G_2, steaming at 10, 12, and 14 knots per hour respectively, would be £100,000, £131,000, and £182,000.

Hence we see how onerous are the obligations which usually impose on mail-packets a rate of speed higher than that which would be adopted for prosecuting a purely mercantile service; and as no service can be permanently and satisfactorily performed which does not pay, it follows that the inadequacy, if any, of a high-speed postal subsidy must be made up by surcharge on passengers and cargo, and is therefore, *pro tanto*, a tax upon trade.

Section H.—Freight as affected (*cæteris paribus*) by variations of the size of ships combined with variations of steaming-speed.

We will suppose the size of the ships to be 5000, 4000, and 3000 tons displacement, and the steaming-speed to be at the rates of 10 knots, 12 knots, and 14 knots per hour respectively.

By reference to the Table (Section H), it appears that, under the special conditions of the service under consideration, by reducing the size of the ship from 5000 to 4000 tons, and increasing the speed from 10 to 12 knots per hour, the expense or required freight charge becomes increased in the ratio of 49 to 66, that is, in the ratio of 100 to 134, or 34 per cent.; and by reducing the size of ship from 5000 to 3000 tons, and increasing the speed from 10 knots to 14 knots, the required freight charge becomes increased in the ratio of 49 to 119, that is, in the ratio of 100 to 243, being an increase of 143 per cent., or a multiple of $2\frac{1}{2}$ times nearly. Hence, assuming the rate of freight by the standard ship A, of 5000 tons, steaming at 10 knots, to be at £1 per ton weight of goods conveyed, the required rate of freight by ship H_1, of 4000 tons, steaming at 12 knots, will be £1 6*s.* 10*d.*, and the required rate of freight charge by ship H_2, steaming at 14 knots per hour, will be at the rate of £2 8*s.* 7*d.* per ton weight of goods conveyed.

The comparative freight charges on 100,000 tons of goods by the vessels A, H_1, H_2, respectively, will be £100,000, £134,000, and £243,000.

Hence also we observe by comparison of ships G_2 and H_2, how important becomes the question of magnitude when the service demands a high rate of speed, the comparative freight charges on 100,000 tons of goods conveyed by the vessels G_2 and H_2, on the service referred to, being £182,000 and £243,000, being an increase of $33\frac{1}{2}$ per cent., solely in consequence of the ship being reduced from 5000 tons displacement to 3000 tons, the coefficient of dynamic duty (14,000) being in both cases the same.

Section I.—Freight as affected by variations of speed combined with variations of the working economy of the engines.

Assuming the rate of speed to be 10 knots, 12 knots, and 14 knots, and the consumption of coal to be 2 lbs., 3 lbs. and 4 lbs. per indicated horse-power per hour respectively, by reference to the Table (Section I.) it appears that by increasing the speed from 10 knots to 12 knots an hour, the rate of consumption of coal being also increased from 2 lbs. to 3 lbs. per indicated horse-power per hour, the required freight charge becomes increased in the ratio of 49 to 72, that is, in the ratio of 100 to 147, or 47 per cent.; and by increasing the speed from 10 knots to 14 knots per hour, the rate of consumption of coal being also increased from 2 lbs. to 4 lbs. per indicated horse-power per hour, the required freight charge becomes increased in the ratio of 49 to 152, that is, in the ratio of 100 to 310, being an increase of 210 per cent., or more than trebled. Hence, assuming the expense or required freight charge by the standard ship A, steaming at 10 knots per hour, and consuming 2 lbs. coal per indicated horse-power per hour, to be at the rate of £1 per ton of goods conveyed, the required freight charge by ship I_1, steaming at 12 knots an hour and consuming 3 lbs. of coal per indicated horse-power per hour, will be at the rate of £1 9*s.* 5*d.* per ton of goods, and the required freight charge by ship I_2, steaming at 14 knots per hour and consuming 4 lbs. of coal per indicated horse-power per hour, will be at the rate of £3 2*s.* per ton of goods conveyed. The comparative freight charges on 100,000 tons of goods by the vessels A, I_1, I_2, respectively, would be £100,000 £147,000, and £310,000.

Hence we see how onerous are the obligations of increased speed, if attempted to be performed with engines of inferior contruction, as respects economy of fuel.

SECTION K.—Freight as affected (*cæteris paribus*) by variations of the speed combined with variations in the type of form, working economy of the engines, and weight of hull.

The object of this section is to show the effect even of small differences of practical construction, when operating collectively to the detriment of a ship, combined with the obligation of increased speed.

By reference to the Table (Section K) it appears that, under the special conditions of the service under consideration, by increasing the speed from 10 to 12 knots, with a ship of inferior type of form, as indicated by the coefficient of performance being reduced from 250 to 225, and of inferior engine arrangement, as indicated by the consumption of fuel being increased from 2 to 3 lbs. per indicated horse-power per hour, the weight of hull being also increased 5 per cent., namely, from 40 per cent. to 45 per cent. of the constructor's load displacement,—by this combination, the expense per ton of goods conveyed becomes increased in the proportion of 49 to 102, that is, in the proportion of 100 to 208, being an increase of 108 per cent., or more than doubled; or, assuming the freight by the standard ship A to be at the rate of £1 per ton, the rate of freight by ship K_1, under the differences above referred to, becomes £2 1*s.* 8*d.*; and it is to observed that if the speed be increased to 14 knots, whilst at the same time the coefficient of performance is reduced to 200, the consumption of fuel increased from 2 lbs. to 4 lbs. per indicated horse-power per hour, and the weight of the hull increased 10 per cent., namely, from 40 per cent. of the load displacement to 50 per cent.,—under these conditions the entire load displacement of the ship K_2 will be appropriated by the weight of the hull, engines, and coal, leaving no displacement whatever available for cargo; that is to say, the vessel K_2 is utterly unable to perform the conditions of the service as a mercantile steamer.

The comparative freight charges on 100,000 tons of goods by the vessels A and K_1 respectively would be £100,000 and £208,000.

Having thus fully explained the Table, it may be observed that, as respects the relation which subsists between the dynamic properties of vessel A, taken as the standard of comparison in the foregoing sections, and the dynamic properties of mercantile steam-ships generally at the present time, it might be regarded as invidious to refer to and particularize the actual performances of vessels presently employed on commercial service; but it may be affirmed generally that the ocean performance of mercantile steam-fleets does not average a coefficient of economic duty, by the formula $\frac{V^3 D^{\frac{2}{3}}}{W}$, exceeding 5600, whilst modern naval architecture and engineering have practically shown that with certain types of form the coefficient of performance may be expected to vary from 250 to 300, and that some engines of modern construction have consumed only from 2 lbs. to $2\frac{1}{2}$ lbs. of coal per indicated horse-power per hour, thus practically constituting a possible coefficient of economic duty as high as 14,000, which has therefore been assigned to ship A in the foregoing table, and whereby, under the conditions of the service referred to, viz. ships of 5000 tons displacement steaming at 10 knots per hour on a passage of 3000 miles, the conveyance of goods per ton weight may be expected to be performed at fully 30 per cent. less cost than would be necessarily incurred under the same circumstances by vessels of the same size, but of which the coefficient of economic duty does not exceed 5600; and this comparative difference would be greatly exceeded if the size of ships be reduced, the length of passage increased, or the speed accelerated.

From the foregoing statements it appears that public interests in the great matter of *Freight* demand that steam-ships only of the most effective construction, as respects hull and engines, be employed on mercantile service. Bad types of hull and wasteful engines, necessarily, as we have seen, enhance freight, increase the cost of production, and consequently curtail consumption, thus constituting a blight on national industry. A check on these evils, highly conducive to the gradual reduction of freight expenses by steam-ships, would at once be instituted by making it a matter of *contract stipulation* that a definite coefficient of *dynamic duty*, by the formula $\frac{V^3 D^{\frac{2}{3}}}{W}$, should be realized on test trial of the ship, at the builder's load displacement and steaming at the stipulated speed. Unquestionably, for years past, in our popular marine engineering, prejudice and expediency have retarded progress; marine engineering practice has not duly availed itself of the established truths and science of the times: expansion, superheating, and surface condensation, now being reanimated as the basis of modern improvements, are but the legacies of a bygone age hitherto neglected.

It is only by directing public opinion to bear on such subjects of general interest, that any prevalent evil can be corrected; and surely an appeal on the important subject of "freight," as affected by differences in the dynamic properties of steam-ships, cannot be more appropriately made to any public body than to the British Association, under the presidency of a man especially distinguished and honoured in the path of practical science, and assembled at Manchester, the birth-place of free trade, and the manufacturing capital of the world.

CHAS. ATHERTON,
Chief Engineer, H.M. Dockyard, Woolwich.

Report on the Progress of Celestial Photography since the Aberdeen Meeting. By WARREN DE LA RUE, *F.R.S.*

AT the Aberdeen Meeting I had the honour of communicating to this Section a Report on the State of Celestial Photography in England, which has since appeared in the Transactions of the Association.

Since that period I have pursued my investigations in this branch of astronomy, and have ascertained some facts which I believe will be of interest to the Meeting.

In the first place I beg to recall to the recollection of Members who may have read my paper, and to re-state for the information of those who have not done so, that it was intended at the period of the Aberdeen meeting that the Kew photo-heliograph should be taken to Spain in order, *if possible*, to photograph the luminous prominences, or, as they are usually called, the red flames, seen on the occasion of a total solar eclipse.

The words implying a doubt as to the success of the undertaking were advisedly inserted, because very little information could be collected from the accounts of those observers who had witnessed previous total eclipses, as to the probable intensity of the light of the corona and red flames in comparison with that of other luminous bodies. My impression was that I should fail in depicting the prominences in the time available for doing so, because I had had the Kew instrument tried upon the moon and had failed utterly in getting even a trace of her image on the sensitive plate, and the corona and prominences together were not supposed to give as much light as the moon. I therefore pointed out the desirability of other astronomers making attempts to depict the phenomena of totality by projecting the image of the prominences direct on to the collodion-plate without enlarging it by a secondary magnifier, as is done in the Kew instrument.

It was fair to assume, with the great experience I had acquired in celestial photography, that I should succeed with the Kew instrument if success were attainable; and I knew that far more reliable results would be obtained by its means than by the other method, which I recommended simply because it seemed to me to offer a greater chance of at least a partial success.

Two theories existed, as is well known, to account for the red prominences. The one, prominently supported by the Astronomer Royal, was that they belonged to the sun; the other, which is still supported even by an astronomer who obtained photographs of them at the last eclipse, was that they are produced by the diffraction of the sun's light by the periphery of the moon.

It will be seen, therefore, not only how essential it was to obtain photographic images of the prominences, but also how important it was to obtain such perfect images of them that they could not be confounded with purely diffractive phenomena if such existed, and that the images should be on such a scale that the defects common to collodion could not be confounded with them. "The pretty near" would have been far more readily accomplished; but having the whole bearing of the subject fully impressed on my mind, I preferred to make a bold venture, and either accomplish what I aimed at or fail entirely.

Fortunately I was successful, and to that success the steadiness of my staff much contributed. We now know that the luminous prominences which surround the sun (for they do belong to him) can be depicted in from 20 to 60 seconds, on the scale of the sun's diameter equal $\frac{4}{3}$ of the object-glass employed. That is to say, an object-glass of 3 inches aperture will give a picture of the prominences surrounding the moon 4 inches in diameter.

The next subject to which I have to call your attention is the photographic depiction of groups of stars—for example, such as form a constellation like Orion,—in other words, the mapping down the stars by means of photography. I have made several experiments in this direction, and have obtained satisfactory results, and I believe that at last I have hit upon an expedient which will render this method of mapping stars easy of accomplishment. The instrument best adapted for this object is a camera of short focal length compared with its aperture, like the ordinary portrait-camera,—the size of the lens being selected to suit the scale of the intended photographic map, and the camera, of course, mounted on an equatorial stand with a clock-work motion.

The fixed stars depict themselves with great rapidity on a collodion-plate; and I have experienced no difficulty in obtaining pictures of the Pleiades by a moderate exposure even in the focus of my telescope; they would be fixed much more rapidly by a portrait-camera. The difficulty in star-mapping does not consist in the difficulty of fixing the images of stars, but in finding the images when they are imprinted; for they are no bigger than the specks common to the best collodion. It is of no service attempting to overcome the difficulty by enlarging the whole picture; but something may be done by causing the images of the stars, which are mere spots, to spread out into a cone of rays by putting the image out of focus and thus imprinting a disc on the plate instead of a point. Last year was so fully employed that I have not yet had time to develope fully this method, but I have ascertained its practicability.

Some curiosity naturally exists as to the possibility of applying photography to the depiction of those wonderful bodies the comets, which arrive generally without anything being known of their previous history and absolutely nothing as to their physical nature. It would be valuable to have photographic records of them, especially of the nucleus and corona, which undergo changes from day to day; and hence such a means of recording these changes as photography offers would be the best, beyond comparison, if the light of the comet were sufficiently intense to imprint itself.

On the appearance of Donati's comet in 1858 I made several unsuccessful attempts to delineate it with my reflector on a collodion film, but without success; and on the appearance of the comet of the present year I made numerous attempts to depict it, not only with my telescope, but also with a portrait-camera; but, even with an exposure of 15 minutes (minutes, not seconds), I failed in getting the slightest impression, even with a portrait-lens. Hence the conclusion may be arrived at that the actinic ray does not exist in sufficient intensity in such a comet as that of 1861 to imprint itself, and therefore photography at present is inapplicable to the recording of the appearances of these wonderful bodies.

I now return to Heliography. Experiments conducted at the Kew Observatory by my request have shown that, for an image of the sun of any given size, when once the aperture of the telescope has been ascertained which is sufficient to produce the picture with the necessary degree of rapidity, it is not beneficial to increase that aperture; that is to say, no more details are depicted, nor does the picture become sharper, so as to bear a greater subsequent enlargement in copying, than when the smaller aperture is used. It has also been established, experimentally, that it is not well to enlarge the image beyond a certain point by increasing the magnifying power of the secondary magnifier and thus to cause the rays to emerge at a very great angle. These results are such as I should have anticipated; but as it was, nevertheless, desirable to produce pictures of the sun's spots, with a view to their close study, on a scale considerably greater than the pictures produced by the Kew instrument, I commenced some preparations at my own observatory for the purpose of trying whether it would be possible to procure such pictures with my reflector. On maturing my plans I found that the apparatus which it would be necessary to use would be so weighty that the telescope would require to be strengthened considerably to support the additional weight in the awkward position in which it would have to be placed; and it did not at first appear how this could be conveniently done.

Ultimately I found the means of adding a radius-bar and of supporting the plate-holder, which carries a plate 18 inches square at a distance of 4 feet from the eye-piece; but here another difficulty occurred, namely, that the image of the sun was so powerfully heating, that, if allowed to remain for a very short time on the instantaneous slide, it heated it and ultimately set fire to some part of the apparatus. A trap easy to be moved over the mouth of the telescope had to be contrived, so as to open just before the instantaneous apparatus was brought into action and shut again immediately afterwards. At last these mechanical difficulties were surmounted, and I commenced my experiments to ascertain the best form for the secondary magnifier: these experiments are still in progress, and some important difficulties remain to be overcome before pictures of the sun's spots will be obtained with that degree of sharpness which shall leave nothing to be desired.

With an ordinary Huyghenian eye-piece, employed as a secondary magnifier and placed somewhat nearer the great mirror than would be its position for the most perfect optical picture, in order to throw the chemical rays further on and thus bring them to focus on the plate, I have obtained some sun-pictures, of very considerable promise, on the extremely large scale of the sun's diameter equal to 3 feet. These pictures have only been very recently procured, and I submit them to the Section because I believe that an interest is felt in the progress of celestial photography, and that the Members prefer to take part in the experiments, as it were, by watching their progress, rather than to wait until the most perfect results have been brought about. I may state that the mechanical and chemical difficulties have been surmounted, and that the only outstanding one is the form of the secondary magnifier*. When this has been worked out, perfect sun-pictures 3 feet in diameter will be obtainable with a telescope of 1 foot aperture, in less than the 20th of a second of time. These pictures, when taken under suitable circumstances, may be grouped so as to produce stereoscopic pictures, which must throw considerable light on the nature of the spots.

It appears to me that such results must be of value to science, and that the records of the state of the sun's photosphere, both as regards spots and other changing phenomena, which are obtainable by means of photography, are worth collecting and discussing, and that ultimately they will throw considerable light on terrestrial meteorology.

It is agreeable to me to work at this problem so as to point out the means by which success is attainable, and I may for a time carry on the records; but it will, on reflection, be seen that these observations (if continued, as they should be, for years) are likely to prove a too serious tax upon the leisure and purse of a private individual.

* Mr. Dallmeyer has lately assisted me in working out this problem, and has produced already two new secondary magnifiers, each of a somewhat different construction. With their aid I made a considerable step in advance, but on November 7th, 1861, was stopped by the lateness of the season.

On the Theory of Exchanges, and its recent extension.
By BALFOUR STEWART, *A.M.*

IT is now somewhere about seventy years since Professor Pierre Prevost of Geneva conceived the rudimentary idea which ultimately became developed into the Theory of Exchanges. In the 'Journal de Physique' for April 1791, we find a memoir by him "On the Equilibrium of Heat;" and from that period until 1832 he wrote many memoirs in confirmation and extension of his views.

The leading feature of this hypothesis is perhaps best expressed in the words which Prevost himself employed to characterize it, when he called his theory that of a moveable equilibrium of temperature.

In order to comprehend more precisely the meaning of this phrase, let us imagine to ourselves a large vacuum-chamber, the walls of which are black, and do not reflect light or heat. Lampblack will therefore be the most appropriate substance with which to cover them. Let us also suppose that the whole chamber is kept at a uniform temperature, and that we place a thermometer in the enclosure. It is well known that this thermometer will ultimately denote the same temperature to whatever portion of the enclosure it may be carried, and that this temperature will be that of the walls of the chamber. The bulb of the instrument is therefore in a state of equilibrium with regard to heat,—a condition of things brought about and sustained, not by currents of air, since the chamber is supposed to be a vacuum, but by that faculty called radiation, in virtue of which a hot body communicates its heat to a distant cold one, even through an absolutely vacant space. This equilibrium may be of two kinds.

1. It may be a statical or tensional equilibrium, that is to say, an equilibrium of repose, in which, from the exact balancing of two opposite tendencies, the bulb of the thermometer neither receives heat nor gives it away.

2. It may also be an active, or, as Prevost calls it, a moveable equilibrium, in which the bulb is constantly giving away heat to the enclosure and receiving back in return precisely as much as it gives away, so that its temperature is neither increased nor diminished.

It was this latter view of the subject which Prevost took,—a view which, besides having a certain amount of inherent probability, has, I think, earned a fair claim, from the great number of facts which it groups together under one law, to be viewed as a correct expression of the truth. To return to our thermometer: the bulb, under the circumstances above mentioned, is supposed by this theory to be constantly giving forth radiant heat at a rate depending only on the temperature of the bulb, and independent of that of the enclosure. On the other hand, it is receiving back from the enclosure an amount of heat depending only on the temperature of the enclosure, and wholly independent of that of the bulb. Thus its expenditure depends upon its own temperature, its receipts upon that of the enclosure, and when these two are of the same temperature, the expenditure of the bulb is exactly balanced by its receipts.

The circumstance which seems to have brought this idea vividly before the mind of Prevost, was the well-known experiment by which Professor Pictet* showed what may be termed the reflexion and concentration of cold. That philosopher took two concave reflectors, making them face one another, and while in the focus of the one he placed a thermometer, in that of the other he placed a lump of ice, the effect of which was that the temperature of the thermometer immediately began to fall. If we admit that cold is a positive principle, and not a mere negation, we shall of course be able to ex-

* Essais de Phys. p. 82.

plain this experiment as easily as if a hot bulb had been placed in the one focus, raising the temperature of the thermometer in the other. But this explanation being inadmissible, it occurred to Prevost that the theory of a moveable equilibrium would account for the phenomenon. Let us adopt this hypothesis, and suppose, in the first instance, that a body of the same temperature as the thermometer is placed in the other focus. It is obvious that this body will not affect the thermometer. Heat is doubtless continually leaving the bulb; but this receives back precisely as much heat as it radiates, a considerable portion of that which it receives being the heat which leaves the body in the opposite focus, and which by the laws of reflexion is concentrated on the bulb. If we next suppose that the other body is of a higher temperature than the thermometer, it is easy to see that the same laws of reflexion will cause an increase of heat to be especially felt by the bulb, since each of the rays of heat which reach it by virtue of the reflector will be more intense than the corresponding ray which it gives away. Should, however, the body in the opposite focus be of a lower temperature than the thermometer, the rays which the former emits, and which, by virtue of the reflector, reach the bulb, will all be less intense than the corresponding rays which the bulb gives forth, and thus the same cause which formerly made the thermometer peculiarly sensitive to an increase in the temperature of the opposite body, will now make it equally sensitive to a diminution of the same.

We are thus furnished by the theory of exchanges with an explanation of this important experiment, which, it is remarked by Prevost in his first memoir of 1791, cannot well be explained by an immoveable equilibrium.

When Leslie* published his experiments on Heat, the theory of exchanges was not slow to exhibit that appropriating quality which is ever the mark of truth. In the hands of Prevost, these experiments, instead of demanding a new hypothesis, were easily explained by means of the old one. Let us take, for instance, the fact discovered by Leslie, that good reflectors of heat, such as metals, are bad radiators. Prevost (in a treatise on Radiant Heat, Paris, 1809) shows how this fact follows from his theory, remarking that in a place of uniform temperature a reflector does not alter the distribution of heat, which it would do if, joined to a good reflecting power, it possessed also that of being a good radiator. It is interesting to note Prevost's mode of expressing himself on this subject, as it shows that he entertained an opinion correct, as far as it went, with regard to internal radiation. He conjectures that a good reflector is a bad radiator, because, as it reflects the heat from without, so it also reflects the heat from within.

Lambert† of Berlin, and Leslie, both proved by experiment that the radiation of a heated surface in any direction is proportional to the sine of the angle which this direction makes with the surface; and it was demonstrated by Fourier‡ that this law is the necessary consequence of the theory of exchanges, in those cases where the reflecting power of the body may be disregarded. He shows, in this demonstration, that if we refuse to admit the truth of the law of sines, and suppose that the intensity of the rays emitted does not vary with the obliquity of the surface, a central molecule can only acquire a temperature equal to half that of the surrounding enclosure. Fourier accompanied this proof with an attempt to account for the law of sines, in which he supposes that there is in every case a physical surface of very small thickness, in which surface the radiant heat emitted by a body takes its rise; but, with the knowledge which we now possess, this cannot, I think, be considered a very happy explanation.

* Inquiry into the Nature and Propagation of Heat. 1804. † Pyrometrie.

‡ Translated in the Philosophical Magazine for February 1833.

I now come to the researches of Dulong and Petit on Radiation* (translated in the 'Annals of Philosophy,' vol. xiii. p. 241), which afford a peculiar evidence in favour of the theory of exchanges. In order to perceive the bearing of this evidence, let us take the case of a black body, say a thermometer with a blackened bulb, cooling in a black enclosure, devoid of air, through the influence of radiation alone. In this case Dulong and Petit proved, by experiment, that the velocity with which the bulb cools will be in every instance accurately represented, if we suppose it to radiate heat at a rate depending only on its own temperature, and to receive back heat at a rate depending only on the temperature of the enclosure. Whatever evidence may be derived from this research is therefore wholly in favour of the theory of exchanges.

The next step in the progress of this theory was one which led to a truer conception of that law of which the law of sines may be considered an approximate expression, and was made by Provostaye and Desains. In a paper published in the 'Annales de Chimie' for 1848, these authors prove experimentally that which was theoretically recognized by Fourier, viz. that, when there is reflexion, the law of the proportionality of the radiating power to the sine of the angle which the ray makes with the surface becomes altered. In the case of glass in a field of constant temperature, they show that the sum of the reflected and radiated heat at all angles will be a constant quantity, and equal to 93·9 per cent. of the lampblack radiation of that temperature, the difference, viz. 6·1 per cent., being supposed to be due to diffusion. The idea which pervades this paper is one which had previously been recognized by Prevost and Fourier, but which proved particularly fertile when worked out by Provostaye and Desains. It may be stated thus. Returning to our hypothetical chamber of constant temperature, with a thermometer placed inside of it, this instrument will give the same indication in whatever manner we alter the substance of the walls, provided their temperature be left the same; whence we may infer that the sum of the radiated and reflected heat from any given portion of the walls which strikes the thermometer, will be independent of the substance of which this portion is composed. We thus perceive that it is not precisely correct to assert that the reflective power of a body varies inversely as its radiative power, the proper statement being that, in the case of constant temperature, the sum of the heat radiated and reflected by a body is a constant quantity.

But these authors were aware that something more than this was necessary in order to ensure a complete equilibrium of temperature; they perceived that the sum of the radiated and reflected heat from a body, while equal to the lampblack radiation, must also be unpolarized, even as the heat from lampblack is unpolarized, in order that both streams under comparison may behave in the same manner with respect to any surface on which they may happen to fall. Since therefore the radiated and reflected heat taken together must be unpolarized, and since the latter portion is at a certain angle polarized in the plane of incidence† it follows that the former, or the radiated heat, must be partly polarized in a plane perpendicular to that of emission. Experimentally this is known to be the case. It had been previously shown by Arago that the rays which leave solid and liquid incandescent bodies obliquely are polarized in a plane perpendicular to that of emission, and Provostaye and Desains found the same law to hold with regard to heat. Their experiments are contained in the 'Annales de Chimie' for 1849, their source of heat being a plate of platinum maintained at a red heat by the flame of an alcohol lamp.

We thus perceive that at this stage of the inquiry a perfectly distinct con-

* Ann. de Chim. et de Phys. vol. vii. p. 113. † Professor Forbes, Edin. Phil. Trans. 1835.

ception had been formed of the character, with respect to intensity and polarization, of the heat emanating from the surface of a body in different directions, necessary in order that the condition of equilibrium of temperature be fulfilled. No attempt, however, seems to have been made to split up this body of heat into its constituent wave-lengths, with the view of ascertaining whether the same laws of equilibrium hold for each of these which hold for the body of heat taken as a whole. Internal radiation, as a subject for experiment, seems also to have been overlooked, and its essential connexion with the theory of exchanges does not appear to have been recognized.

In March 1858, I communicated to the Royal Society of Edinburgh the results of an experimental research having reference to the two points just mentioned. By means of a thermo-electric pile and galvanometer the following facts were established:—

1. The radiating power of thin polished plates of different substances was found to vary as their absorptive power; so that the radiation of a plate of rock-salt was only 15 per cent. of the total lampblack radiation for the same temperature.

2. It was shown that the radiation from thick plates of diathermanous substance is greater than that from thin plates, no such difference being manifested when the substances are athermanous.

3. It was found that heat radiated by a thin diathermanous plate is less transmissible through a screen of the same material as the heated plate than ordinary or lampblack heat, this difference being very marked in the case of rock-salt.

4. Lastly, heat from a thick diathermanous plate is more easily transmitted through a screen of the same nature as the source of heat than that from a thin plate.

All these facts are easily explained by means of the theory of exchanges. Let us recur to the hypothetical chamber before introduced, the sides of which are covered with lampblack and kept at a constant temperature, and let us hang up in this chamber two slices of polished rock-salt, of which the one is twice as thick as the other; these plates will ultimately attain the temperature of the sides of the chamber, when their radiation will exactly equal their absorption. Now, since the thick plate will absorb more than the thin one of the heat which falls upon them from the walls, it will therefore also have a greater radiation than the latter; as, however, both plates, being diathermanous, absorb only a small portion of the heat which falls upon them, the radiation of both will be comparatively small. We have thus an explanation of the experimental fact that diathermanous bodies radiate very little heat, and that their radiation increases with their thickness. We see also why in an athermanous body an increase of thickness does not augment the radiation,—the reason being that, since it is already athermanous, this increase cannot possibly make it absorb more heat, and therefore cannot make it radiate more.

We are therefore brought to recognize internal radiation as a consequence of the theory of exchanges; but the question now arises, Is the radiation of a particle independent of its distance from the surface? A little reflection will enable us to answer this question in the affirmative; for it is evident (neglecting the surface reflexion, which does not really alter the result arrived at) that the amount of heat absorbed by two plates of any substance placed loosely together is not different from that absorbed by a plate equal in thickness to the two, and hence the radiation is the same also in both these cases. I have likewise shown experimentally that the heat from two plates of rock-salt placed the one behind the other, is the same as that from a single plate equal in thickness to the two.

Presuming therefore that the radiation of a particle is independent of its distance from the surface, let us endeavour to realize what takes place in the interior of a substance of indefinite thickness in all directions, and kept at a constant temperature. Let us suppose that a stream of radiant heat is constantly flowing past a particle A in the direction of the next particle B. Now since the radiation of B is by hypothesis equal to that of A, the absorption of B must be equal to that of A. But let us notice what has happened to the stream of heat in passing A. Part of it has been absorbed by A, but on the other hand it has been recruited by the radiation of A, and this being equal to the absorption, the stream of heat when it has passed A will be found unaltered by its passage with regard to quantity. But it must also remain unaltered with respect to quality, otherwise when it falls on B, the amount absorbed by B will be different from that absorbed by A; and hence the radiation of B will be different from that of A, which is contrary to hypothesis. The absorption of A is therefore equal to its radiation in *quality* as well as in *quantity*; or in other words, we have a separate equilibrium for every description of heat. We have thus an explanation of the experimental fact already alluded to, that a body is particularly opake with regard to that heat which it radiates, since we see that a substance is predisposed to radiate that description of heat which it absorbs.

It is easy also to perceive why heat from a thick plate may be more easily transmitted through a screen of the same nature as the source of heat, than that from a thin plate, the reason being that the rays from the furthest portion of the heated plate have already been sifted in their passage through the plate, and hence that that portion of them which escapes is more easily able to penetrate a screen of the same material.

I have before alluded to a conclusion derived by Provostaye and Desains from the theory of exchanges, that in an enclosure of constant temperature the sum of the radiated and reflected heat from any portion of the walls is equal to the lampblack radiation of that temperature. This is a case which evidently comes under the scope of the law, which provides for a separate equilibrium for every description of heat; hence we may assert that the sum of the radiated and reflected heat is in this case equal to the lampblack radiation in quality as well as in quantity; and we are thus also led to perceive why opake bodies heated up to the same temperature always radiate the same description of heat.

We come now to the subject of light; and since radiant light and heat have been shown by Melloni, Forbes, and others to possess very many properties in common, it was of course only natural to suppose that facts analogous to those mentioned should hold also with regard to light. One instance will at once occur in which this analogy is perfect. For, as all opake bodies heated up to the same temperature radiate the same description of heat, so also when their common temperature is still further increased, they acquire a red heat, or a yellow heat, or a white heat simultaneously.

The idea of applying these views to light had occurred independently to Professor Kirchhoff and myself; but, although Kirchhoff slightly preceded me in publication, it will be convenient to defer the mention of his researches till I come to the subject of lines in the spectrum.

In February 1860, I communicated to the Royal Society of London a paper in which certain properties of radiant light were investigated, similar to those already treated of with respect to heat.

In this paper it was mentioned that the amount of light radiated by coloured glasses is in proportion to their depth of colour, transparent glass giving out very little light; also that the radiation from red glass has a greenish tint, while that from green glass has a reddish tint.

It was also mentioned that polished metal gives out less light than tarnished metal, and that, when a piece of black and white porcelain is heated in the fire, the black parts give out much more light than the white, thereby producing a curious reversal of the pattern.

All these facts are comprehended in the statement that in a constant temperature the absorption of a particle is equal to its radiation, and that for every description of light.

It was also noticed that all coloured glasses ultimately lose their colour in the fire as they approach in temperature the coals around them, the explanation being, that while red glass, for instance, gives out a greenish light, it passes red light from the coals behind it, while it absorbs the green, in such a manner that the light which it radiates precisely makes up for that which it absorbs, so that we have virtually a coal radiation coming partly *from* and partly *through* the glass.

In another paper communicated to the Royal Society in May of the same year, it was shown that tourmaline, which absorbs in excess the ordinary ray of light, also radiates, when heated, this description of light in excess, but that when the heated tourmaline is viewed against an illuminated background of the same temperature as itself this peculiarity disappears.

It is now time to advert to the spectrum observations which have recently excited so much attention, and which are intimately connected with the subject of this Report. Our countryman Wollaston*, and after him Fraunhofer, were the first to show that in the solar spectrum numerous dark bands occur which indicate the absence of light of certain definite refrangibility. Other new bands were artificially produced by Sir David Brewster† in his remarkable experiment, in which the spectrum was made to pass through nitrous-acid gas; and it was thus rendered probable that those which occur in the solar spectrum are also in some way due to absorption. Professor W. H. Miller of Cambridge, and the late Professor Daniell‡, extended this property to chlorine, iodine, bromine, euchlorine, and indigo.

When the spectra produced by the ignition of various substances were examined by Sir D. Brewster§, Sir J. Herschel‖, Messrs. Talbot¶, Wheatstone**, W. A. Miller††, and others, their contrast to the solar spectrum was exceedingly remarkable.

While the latter may be described as a continuous spectrum intersected with dark bands, the spectra of artificial substances are for the most part made up of bright, discontinuous, highly characteristic bands of light in a dark background, and their general appearance is that of the solar spectrum reversed‡‡. I think Fraunhofer was the first to notice that a bright band corresponding in refrangibility to the double dark band D of the solar spectrum was produced by the yellow light of a flame containing sodium; and this ray was shown by Professor W. A. Miller§§ to occur in the flames of lime, strontia, baryta, zinc, iron, and platinum, while, according to Angström, it was found in the electric flames of every metal examined by him. Professor Swan‖‖ afterwards showed that an exceedingly small proportion of common salt called forth this line. All these philosophers, but particularly Angström,

* Philosophical Transactions 1802, p. 378.

† London and Edinb. Philosophical Magazine, vol. ii. p. 381.

‡ Philosophical Magazine, 1833.

§ Edinburgh Phil. Trans. 1822.

‖ Edinburgh Phil. Trans. 1822.

¶ Brewster's Journal of Science, vol. v.

** British Association Report for 1835.

†† British Association Report for 1845, or Philosophical Magazine, vol. xxvii. p. 81.

‡‡ Professor W. A. Miller exhibited at this Meeting of the British Association (Manchester 1861) photographs of the spectra of several metals, and I have since been informed that he is pursuing the subject with success.

§§ Philosophical Magazine, August 1845.

‖‖ Edinburgh Transactions, 1856.

seem to have been impressed with the idea that the same physical cause which produces the dark bands of the solar spectrum, produces also the bright bands in the spectra of incandescent bodies.

In a paper by Angström* (a translation of which will be found in the 'Philosophical Magazine' for May 1855), the author refers to a conjecture by Euler, that a body absorbs all the series of oscillations which it can itself assume; "and it follows from this, says Angström, that the same body when heated so as to become luminous must emit the precise rays which at ordinary temperatures are absorbed;" after which remarkable conjecture, now amply verified by experiment, he goes on to say, "I am therefore convinced that the explanation of the dark lines in the solar spectrum embraces that of the luminous lines in the electric spectrum."

In connexion with this subject it may not be out of place to introduce the following extract of a letter from Prof. W. Thomson to Prof. Kirchhoff, dated 1860. Professor Thomson thus writes:—"Professor Stokes mentioned to me at Cambridge some time ago, probably about ten years, that Professor Miller had made an experiment testing to a very high degree of accuracy the agreement of the double dark line D of the solar spectrum with the double bright line constituting the spectrum of the spirit-lamp burning with salt. I remarked that there must be some physical connexion between two agencies presenting so marked a characteristic in common. He assented, and said he believed a mechanical explanation of the cause was to be had on some such principles as the following:—Vapour of sodium must possess by its molecular structure a tendency to vibrate in the periods corresponding to the degrees of refrangibility of the double line D. Hence the presence of sodium in a source of light must tend to originate light of that quality. On the other hand, vapour of sodium in an atmosphere round a source, must have a great tendency to retain in itself, *i. e.* to absorb and to have its temperature raised by light from the source, of the precise quality in question. In the atmosphere around the sun, therefore, there must be present vapour of sodium, which, according to the mechanical explanation thus suggested, being particularly opake for light of that quality, prevents such of it as is emitted from the sun from penetrating to any considerable distance through the surrounding atmosphere. The test of this theory must be had in ascertaining whether or not vapour of sodium has the special absorbing power anticipated. I have the impression that some Frenchman did make this out by experiment, but I can find no reference on the point."

The experiment alluded to by Professor Stokes in this conversation was made by M. Foucault, who in July 1849 communicated to the Institute the result of some observations on the voltaic arc formed between charcoal poles. He found, to use his own words, that this arc, placed in the path of a beam of solar light, absorbs the rays D, so that the dark line D of the solar light is considerably strengthened when the two spectra are exactly superposed. When, on the contrary, they jut out one beyond the other, the line D appears darker than usual in the solar light, and stands out bright in the electric spectrum, which allows one easily to judge of their perfect coincidence. Thus the arc, he continues, presents us with a medium which emits the rays D on its own account, and which at the same time absorbs them when they come from another quarter.

To make the experiment in a manner still more decisive, Foucault projected on the arc the reflected image of one of the charcoal points, which, like all solid bodies in ignition, give no lines; and under these circumstances the line D appeared as in the solar spectrum.

* Poggendorff's 'Annalen,' vol. xciv. p. 141.

In October 1859, Professor Kirchhoff of Heidelberg made a communication to the Berlin Academy on the subject of Fraunhofer's lines, which, along with Foucault's communication, has been inserted by Professor Stokes in the 'Philosophical Magazine' for March 1860. Professor Kirchhoff thus describes the result of his experiments:—

"On the occasion of an examination of the spectra of coloured flames, not yet published, conducted by Bunsen and myself in common, by which it has become possible for us to recognize the qualitative composition of complicated mixtures from the appearance of the spectrum of their blowpipe-flame, I made some observations which disclose an unexpected explanation of the origin of Fraunhofer's lines, and authorize conclusions therefrom respecting the material constitution of the atmosphere of the sun, and perhaps also of the brighter fixed stars.

"Fraunhofer had remarked that in the spectrum of the flame of a candle there appear two bright lines, which coincide with the two dark lines D of the solar spectrum. The same bright lines are obtained of greater intensity from a flame into which some common salt is put. I formed a solar spectrum by projection, and allowed the solar rays concerned, before they fell on the slit, to pass through a powerful salt-flame. If the sunlight were sufficiently reduced, there appeared in place of the two dark lines D two bright lines; if, on the other hand, its intensity surpassed a certain limit, the two dark lines D showed themselves in much greater distinctness than without the employment of the salt-flame.

"The spectrum of the Drummond light contains, as a general rule, the two bright lines of sodium, if the luminous spot of the cylinder of lime has not long been exposed to the white heat; if the cylinder remains unmoved these lines become weaker, and finally vanish altogether. If they have vanished, or only faintly appear, an alcohol flame into which salt has been put, and which is placed between the cylinder of lime and the slit, causes two dark lines of remarkable sharpness and fineness, which in that respect agree with the lines D of the solar spectrum, to show themselves in their stead. Thus the lines D of the solar spectrum are artificially evoked in a spectrum in which naturally they are not present.

"If chloride of lithium is brought into the flame of Bunsen's gas-lamp, the spectrum of the flame shows a very bright sharply defined line, which lies midway between Fraunhofer's lines B and C. If, now, solar rays of moderate intensity are allowed to fall through the flame on the slit, the line at the place pointed out is seen bright on a darker ground; but with greater strength of sunlight there appears in its place a dark line, which has quite the same character as Fraunhofer's lines. If the flame be taken away, the line disappears, as far as I have been able to see, completely.

"I concluded from these observations that coloured flames in the spectra of which bright sharp lines present themselves, so weaken rays of the colour of these lines, when such rays pass through the flames, that in place of the bright lines dark ones appear as soon as there is brought behind the flame a source of light of sufficient intensity, in the spectrum of which these lines are otherwise wanting. I conclude further, that the dark lines of the solar spectrum which are not evoked by the atmosphere of the earth, exist in consequence of the presence, in the incandescent atmosphere of the sun, of those substances which in the spectrum of a flame produce bright lines at the same place. . . . .

"The examination of the spectra of coloured flames has accordingly acquired a new and high interest; I will carry it out in conjunction with Bunsen as far as our means allow. In connexion therewith we will investigate the weakening of rays of light in flames that has been established by my observations. In the course of the experiments which have at present been instituted by us in this direction, a fact has already shown itself which seems to us to be of great importance. The Drummond light requires, in order that the lines D should come out in it dark, a salt-flame of lower temperature. The flame of alcohol containing water is fitted for this, but the flame of Bunsen's gas-lamp is not. With the latter the smallest mixture of common salt, as soon as it makes itself generally perceptible, causes the bright lines of sodium to show themselves."

This interesting investigation, which was translated by Professor Stokes in the 'Philosophical Magazine' for March 1860, came before me in time to permit of my adding a supplement to a paper "On the Light radiated by Heated Bodies," which has been already alluded to. In this supplement it was attempted to explain the fact noticed by Kirchhoff, that the Drummond light requires, in order that the lines D should come out in it dark, a salt-flame of lower temperatnre. This is a phenomenon analogous to that presented when a piece of ruby glass is heated in the fire. As long as the ruby glass is of a lower temperature than the coals behind it, the light given out is of a red description, because the ruby glass stops the green: the green light is therefore precisely analogous to the line D which is stopped by an alcohol flame into which salt has been put. Should, however, the ruby glass be of a much higher temperature than the coals behind it, the greenish light which it radiates overpowers the red which it transmits, so that the light which reaches the eye is more green than red. This is precisely analogous to what is observed when a Bunsen's gas-flame with a little salt is placed before the Drummond light, when the line D is no longer dark, but bright.

Such was the explanation; but in the meantime Professor Kirchhoff had not been idle. Pondering on the circumstance that the Drummond light requires a salt-flame of lower temperature, in order that the line D should come out in it dark, he was soon led to see the connexion between this fact and the theory of exchanges. In a communication laid before the Berlin Academy of Sciences on the 15th of December 1859, he had already recognized this connexion, and in a subsequent communication to Poggendorff's 'Annalen,' dated January 1860, he shows it to be a mathematical consequence of the theory of exchanges that a definite relation must subsist between the radiating and absorbing power of bodies for individual descriptions of light and heat.

This investigation proceeds upon the assumption that in an enclosure of uniform temperature the distribution of radiant heat will remain unaltered, if any one body be removed and another of a different substance, but similar dimensions, be substituted exactly in its place. The reasoning is somewhat elaborate, but ultimately leads the author to a definite relation between the radiating and absorbing powers of bodies for individual descriptions of light and heat.

He has expressed this relation very clearly in the following form.

Let R denote the intensity of radiation of a particle for a given description of light at a given temperature, and let A denote the proportion of rays of this description incident on the particle which it absorbs; then $\frac{R}{A}$ has the same value for all bodies at the same temperature, that is to say, this quotient is a function of the temperature only.

Professor Kirchhoff in this communication details some experiments which he had made upon incandescent bodies. In confirmation of his assertion that a body which remains perfectly transparent at the highest temperature never becomes red-hot, he placed in a platinum ring of about 5 millims. diameter a small portion of phosphate of soda, and heated it in the dull flame of Bunsen's lamp. The salt melted, formed a fluid lens, and remained perfectly transparent; it, however, emitted no light, while the platinum ring with which it was in contact glowed brilliantly. Kirchhoff also showed that a plate of tourmaline cut parallel to the axis which absorbs the ordinary rays in excess, radiates the same in excess. These results are similar to those which I communicated shortly afterwards to the Royal Society, and which have been already mentioned.

It was likewise stated by Kirchhoff in this paper, that Bunsen and he had reversed the brighter lines of the spectra of potassium, calcium, strontium, and barium, by exploding before the slit of the spectral instrument mixtures of sugar of milk and chlorates of the respective metals during the passage of the sun's rays.

Allusion has already been made to Kirchhoff's application of this law of reversal, in order to determine the constituents of the solar atmosphere. By means of this principle he has been enabled, he believes, to trace the presence of iron and other metals in the photosphere of our luminary, having found that the bright lines which occur in the electric spectra of those metals correspond in position with dark lines in the solar spectrum. "Iron," he says, "is remarkable on account of the number of the lines which it causes in the solar spectrum. Less striking, but still quite distinctly visible, are the dark solar lines coincident with the bright lines of chromium and nickel. The occurrence of these substances in the sun may therefore be regarded as certain. Many metals, however, appear to be absent; for although silver, copper, zinc, aluminium, cobalt, and antimony possess very characteristic spectra, still these do not coincide with any (or at least with any distinct) dark lines of the solar spectrum."

It has been shown, in the course of this Report, how the law which connects together the radiating and absorbing power of bodies for individual descriptions of heat or light follows immediately from the theory of exchanges. But physicists have been anxious to establish this law as the result of some simple fundamental property of matter. Euler, we have seen, and Angström after him, predicted its existence, assuming as a fundamental principle, that a body absorbs all the series of oscillations which it can itself assume.

Professor Stokes also, in commenting on the discovery of Foucault and Kirchhoff (Philosophical Magazine, March 1860), uses these words:—"The remarkable phenomenon discovered by Foucault, and rediscovered and extended by Kirchhoff, that a body may be at the same time a source of light giving out rays of a definite refrangibility, and an absorbing medium extinguishing rays of the same refrangibility which traverse it, seems readily to admit of a dynamical illustration borrowed from sound. We know that a stretched string which on being struck gives out a certain note (suppose its fundamental note) is capable of being thrown into the same state of vibration by aërial vibrations corresponding to the same note. Suppose now a portion of space to contain a great number of such stretched strings, forming thus the analogue of a 'medium.' It is evident that such a medium on being agitated would give out the note above mentioned, while on the other hand, if that note were sounded in air at a distance, the incident vibrations would throw the strings into vibration, and consequently would themselves be gradually extinguished, since otherwise there would be a creation of *vis viva*. The optical application of this illustration is too obvious to need comment."

Professor Tyndall also, in the Bakerian Lecture for this year, "On the Absorption and Radiation of Heat by Gases and Vapours, and on the Physical

Connexion between Radiation, Absorption, and Conduction," has given a very lucid statement of a hypothesis of this kind, accompanied with a remarkable experimental verification.

On the supposition that an ether envelopes the molecules of matter (just as the air surrounds the string of a musical instrument), the author points out that the reciprocity of absorption and radiation is a necessary mechanical consequence of this theory, on the principle of the equality of action and reaction. He then goes on to say, "the elementary gases which have been examined all exhibit extremely feeble powers, both of absorption and radiation, in comparison with the compound ones. In the former case we have oscillating atoms, in the latter oscillating systems of atoms. Uniting the atomic theory with the conception of an ether, it follows that the *compound* molecule, which furnishes *points d'appui* to the ether, must be capable of accepting and generating motion in a far greater degree than the single atom, which we may figure to our minds as an oscillating sphere. Thus oxygen and hydrogen, which taken separately or mixed mechanically produce a scarcely sensible effect, when united chemically to form oscillating systems, as in aqueous vapour, produce a powerful effect. Thus also nitrogen and hydrogen, which when separate or mixed produce but little action, when combined to form ammonia produce a great action. So also nitrogen and oxygen, which, as air, are feeble absorbents and radiators, when united to form oscillating systems, as in nitrous oxide, are very powerful in both capacities."

This great absorbing power which belongs to a compound molecule is a very interesting result, and seems to be well explained by this hypothesis; but whether all compound gases without exception are more absorptive than their components, in the absence of experimental evidence may, I think, admit of being questioned.

It has been shown in this Report that internal radiation follows immediately from the theory of exchanges, and is independent of the distance from the surface. In an uncrystallized medium, this radiation will, by the principle of sufficient reason, be equal in all directions; but here a question arises which shapes itself thus:—Let us suppose a polished surface of indefinite extent, bounding an uncrystallized medium of indefinite thickness; and placed opposite to this surface and parallel to it let us imagine an indefinitely extended surface of lampblack; and finally, let the whole arrangement be kept at a constant temperature. Now we know the quantity of heat which radiates from the lampblack in directions making different angles with the surface; and since the proportion of this heat which after striking the polished surface penetrates it in a certain direction must be equal to the quantity of heat which leaves this surface from the interior in the same direction, it can be readily conceived how, by means of optical laws, we may be enabled to tell the internal radiation, in different directions, of the solid to which this surface belongs. It is remarkable that the internal radiation deduced by this method for an uncrystallized body is equal in all directions—a result which we have seen may also be arrived at by the principle of sufficient reason.

In order to define internal radiation, let us conceive a square unit of surface to be placed in the midst of a solid of indefinite thickness on all sides, and consider the amount of radiant heat which passes across this square unit of surface in unit of time, in directions very nearly perpendicular to the surface, and comprehending an exceedingly small solid angle $\delta\phi$. Call this heat $R\delta\phi$, then R may be viewed as the intensity of the radiation in this direction.

Now if R denote the radiation of lampblack, and μ the index of refraction of an uncrystallized medium, it may be shown that the internal radiation as thus defined is equal to $R\mu^2$.

Before concluding this Report, there is one fact which I think internal radiation may serve to explain in some such way as the following. Suppose we have two substances opposite one another, one having the temperature of 0°, and the other of 100°, the latter will of course lose heat to the former; let us call its velocity of cooling 100. Suppose now that, while the first surface still retains the temperature 0°, the second has acquired that of 400°; then we might naturally expect the velocity of cooling to be denoted by 400; but by Dulong and Petit's law it is much greater. The reason of the increase may perhaps be thus accounted for:—At the temperature of 100° we may suppose that only the exterior row of particles of the body supplies the radiation, the heat from the interior particles being all stopped by the exterior ones, as the substance is very opake for heat of 100°; while at 400°, for the heat of which the particles are less opake, we may imagine that part of the radiation from the interior particles is allowed to pass, thereby swelling up the total radiation to that which it is by Dulong and Petit's law.

On the Recent Progress and Present Condition of Manufacturing Chemistry in the South Lancashire District. *By* Drs. E. Schunck, R. Angus Smith, *and* H. E. Roscoe.

It has been frequently suggested by persons engaged in manufacturing chemistry in this neighbourhood, that, as Manchester is the centre of a large district in which the growth of those branches of industry immediately dependent upon chemical science has been so extraordinarily rapid, and in which their extent is now so vast, it would be fitting and desirable to present to the Chemical Section of the British Association, at its Meeting in Manchester, a short report on the recent progress and present condition of the chemical manufactures of the South Lancashire district.

In drawing up such a Report, those to whom the task of collecting and editing the matter was entrusted have endeavoured, in the first place, to give some idea of the progress which has been made in the trade, by describing as concisely as possible those new processes, or those improvements on old ones, in which any point of sufficient scientific interest presented itself; and in the second place, to give a statistical account, as accurate as possible, of the present yield of the very large number of chemical works in the South Lancashire district. As a description of the rise of the Lancashire chemical trade from its commencement would have much exceeded the limits of such a Report, the authors decided upon confining themselves, as a rule, to the collection of facts regarding the improvements and new processes introduced during the last ten years. Notwithstanding this limitation it has, however, been found that the labour of arranging the matter was much more considerable than was at first supposed; and the authors feel that, in spite of the great amount of time and trouble they have expended upon it, the Report is still far from complete, and they fear that in one or two minor points inaccuracies may have crept in: they believe, however, that several points of great scientific interest will be presented to the notice of the Section—points which hitherto have only been known to the practical manufacturer; and they feel sure that the statistics they have been able to collect will give to the scientific world a notion of the importance, in a national point of view, of the chemical trade of South Lancashire.

The authors wish especially to remark that by far the largest portion of the facts and statements which they are about to lay before the Section have been verbally communicated to them by various gentlemen practically engaged in the chemical manufactures of this neighbourhood, who have, in a most liberal manner, not only opened their works to minute inspection, but have themselves devoted a considerable amount of time and personal labour in minutely explaining all those processes which they deemed of scientific interest, thus throwing open their accumulated store of practical as well as theoretical experience.

Where the attention and interest shown by all the numerous gentlemen to whom the authors had occasion to apply has been so great, it appears almost invidious to mention any names; but in thanking all, the authors cannot forbear to state that to Messrs. Roberts, Dale and Co. of Cornbrook, Mr. Gossage and Mr. Deacon of Widnes, Mr. Spence of Pendleton, Mr. Shanks of St. Helens, and Mr. Higgin and Mr. Hart of Manchester they are especially indebted for a large amount of valuable information.

In conclusion, it may be stated that it has been the aim throughout the Report to describe the various improvements effected during the last ten years so far only as they are of scientific interest, and carefully to avoid entering into those details of manufacture which to a great extent regulate the economic production of the article, and which, though they are all-important to the trader, are of slight interest to the man of science.

I. Sulphuric Acid.

No substance produced by the manufacturing chemist is equal in importance to sulphuric acid, since it is quite indispensable in the production of many other articles, as well as in many manufacturing processes. In the production of soda-ash, and consequently of soap and glass, of muriatic, nitric, and other acids, of alum, sulphate of copper, bleaching powder, &c., in bleaching and dyeing, its use is quite essential. To produce it economically on the large scale is therefore an object of considerable importance, and numerous improvements have consequently been introduced into the manufacture with the view of bringing it to the highest state of perfection. In order to give an idea of the degree of economy practised, we may mention that an eminent manufacturer informs us that he obtains from 100 parts of sulphur 280-290 parts of sulphuric acid of sp. gr. 1·85, which, even supposing the sulphur to be pure, is as near the calculated quantity (306) as can be expected in practice. Very few manufacturers, however, employ sulphur; most of them use pyrites, the only objection to the latter being that it contains arsenic, so that the product is consequently contaminated with arsenious acid. The Irish pyrites contains 33 per cent. of sulphur, whilst the Spanish pyrites contains as much as 46 per cent. The ordinary burner for pyrites is well known, and answers sufficiently well when the ore is in large lumps, since the quantity of sulphur left in the residue does not exceed 3 per cent.; but considerable difficulty is experienced in operating on the smaller pieces and powder, technically called *smalls*. In burning these in the ordinary way, in the case of Spanish pyrites, from 8 to 10 per cent. of sulphur remains behind and is lost. By mixing them with clay and forming the mixture into balls before burning, this loss may be reduced to about 4 per cent. It is indeed possible to continue the operation until the quantity of sulphur left unconsumed amounts to only 2 per cent., but the time required for this purpose is found to be too long to make it worth while to do so. Mr. Spence of Manchester has, however, devised a plan for effecting this object in an economical manner, which may be shortly described as follows:—In the first place the smalls are riddled out, the large lumps being put into the ordinary burner. The smalls are then placed on a hearth of firebrick 40 feet long and 6 or 7 feet wide, which is heated from below, and has a current of air passing over it to burn the sulphur and convey the sulphurous acid into the chambers. The material is introduced at the end furthest from the fire, where it only experiences a gentle heat, and is gradually moved forward to where the heat is greatest. If the ore is ground, the sulphur may in this kiln be completely burnt. We may mention, by the way, that the introduction of Spanish and Portuguese pyrites has caused the rise of a new branch of industry in the extraction of the small quantity of copper which these ores contain. The manufacturers do not, however, find it advisable in general to extract the copper themselves; they sell it to the smelter.

The manufacturers of oil of vitriol have recently availed themselves of another source of sulphurous acid. In Hill's process of purifying gas, hydrated peroxide of iron is employed instead of lime. After being used for some time the material is exposed to the atmosphere, in order to re-oxidize the reduced oxide of iron. The process is repeated thirty or forty times, after which it can no longer be employed for the purification of gas. It contains, however, 40 per cent. of sulphur, and the manufacturers make use of it in the same way as pyrites for the production of sulphurous acid. From 1 ton of the material they obtain about $1\frac{1}{4}$ ton of hydrated sulphuric acid.

Mr. Harrison Blair's improved sulphur-burner is especially valuable as economizing space in the chambers, by preventing the sulphurous acid from being diluted with too large an excess of air, as is the case with the ordinary sulphur-burners. In this arrangement the sulphur falls into the burner through a vertical hopper, air being admitted by an opening in front in sufficient quantity to cause combustion of a portion of the sulphur, and by the heat thus evolved to melt and volatilize the remainder. The vapour of the sulphur is then supplied with a jet of air, from the side, carefully regulated, and burns with a flame of great size. By means of this arrangement, one chamber of a capacity of 25,000 cubic feet is stated to produce weekly 21 tons of rectified acid, whereas, by using the ordinary burner, a chamber of the same capacity would produce only 11 tons.

The tendency in this district has been to increase the size of the sulphuric-acid-chambers. The largest that we have heard of has a capacity of 112,000 cubic feet.

Many manufacturers employ Gay-Lussac's method, invented sixteen or seventeen years ago for economizing nitric oxide. Pure sulphuric acid of sp. gr. 1·75 is poured down a column filled with coke, so as completely to moisten it. The waste nitrous fumes from the chambers, which would otherwise be lost, are then passed through the column and absorbed. The liquid is diluted with water to a sp. gr. of 1·50 and heated with steam, nitrous fumes are evolved, which pass off into the chambers and are used instead of fresh gas. By this means a saving of more than 50 per cent. of nitrate of soda is effected. Others, however, do not employ this method, as they find that with the present low price of nitrate of soda, £12 per ton, it does not pay to collect and absorb the waste oxides of nitrogen.

The use of platinum stills for the rectification of sulphuric acid has been almost entirely abandoned, and their place supplied by glass retorts, which are now made much larger and of better quality than formerly. They are placed either over the naked fire, or else in iron pots containing a little sand; and when carefully protected from currents of air, the breakage is not found to be excessive. The acid thus obtained is said to be more transparent and less coloured than that prepared with platinum.

We estimate the weekly production of sulphuric acid of sp. gr. 1·85, in this district, exclusive of that which is used in the manufacture of soda-ash, at about 700 tons.

II. The Manufacture of Soda.

In the most important chemical manufacture of the district, that of soda-ash, but few changes in principle have taken place during the last ten years, the essential points of the original method of Leblanc (1797) being still adhered to, although minor alterations have been introduced in the various processes. The extent of the manufacture has, however, largely increased since the year 1851. The value of alkali made annually in England is estimated at two million pounds sterling; of this, half is made in the South Lancashire and half in the Newcastle district. In the year 1860 the average quantity of common salt (chloride of sodium) decomposed per week in the alkali works of the South Lancashire district amounted to 2600 tons. This quantity of salt requires for its decomposition 3110 tons of sulphuric acid of sp. gr. 1·60, and produces 3400 tons of hydrochloric acid of sp. gr. 1·15. The weight of salt decomposed serves as the simplest measure of the activity of the alkali trade, as this raw material is worked up into a variety of products the exact relative quantities of which it is not easy to estimate. Through the kindness of the leading firms in the alkali trade in this neighbourhood we are, however, enabled to lay before the Section a reliable approximate estimate of the total quantities of these various products now made in the district; viz. salt-cake, soda-ash, soda crystals, caustic soda, and bicarbonate of soda:—

Statistics of the Lancashire Alkali-Trade, 1861.

	Tons.
Common salt (Na Cl) decomposed per week	2600
Sulphuric acid (sp. gr. 1·6) used	3110
Hydrochloric acid (sp. gr. 1·15) produced	3400
Soda-ash sold per week	1800
Salt-cake sold per week	180
Soda crystals ($NaO\ CO_2+10\ HO$) sold per week	170
Bicarbonate of soda sold per week	225
Caustic soda (solid) sold per week	90

Since the year 1852 the alkali-trade in the South Lancashire district has more than tripled, in that year only 772 tons of common salt being consumed per week.

These large quantities of products now manufactured are derived from about twenty-five works, varying from a yield of 175 to 25 tons of ash per week; the chief localities in which the trade is carried on are, St. Helens, Runcorn Gap, and Widnes Dock near Warrington, the neighbourhood of Bolton, and Newton Heath near Manchester*. Some idea may be formed of the extent of the Lancashire alkali-trade when it is stated that two large firms are engaged solely in breaking the limestone used by the alkali makers in the Widnes district alone.

It would far exceed the limits of this Report were we even to mention the very numerous patents for improvements in the alkali-trade taken out since 1851. Suffice it to say that none have succeeded in materially altering the process. Many plans have been proposed for avoiding the loss of sulphur,

* The numbers here given include the yield of three works beyond the limit of the county—two situated on the Cheshire side of the Mersey at Runcorn, and one at Flint—but all sending their products to the Lancashire markets.

the great drawback of Leblanc's original method; but none have been as yet found to be practically successful, if, indeed, we except a process used by the St. Helens Patent Alkali Company, in which the bisulphide of iron (iron pyrites), being roasted in a reverberatory furnace with common salt, yields volatile sesquichloride of iron, salt-cake, and peroxide of iron, which are separated by lixiviation. A process, theoretically most promising, has been proposed by Mr. Gossage, to whom the alkali-trade owes so much, by which all loss of sulphur is avoided; but even this plan has not yet been successfully worked. It depends upon the following facts: (1) that moist carbonic acid decomposes sulphide of sodium, forming carbonate of soda and sulphuretted hydrogen; and (2) that dry peroxide of iron is reduced by sulphuretted hydrogen—free sulphur, water, and protoxide of iron being formed,—the latter part of the process having been patented by Mr. Thomas Spencer in 1859. The salt-cake, made in the usual way, is in this process reduced by coal, and the fused sulphide allowed to flow through a tower filled with heated coke, in which it meets a current of moist carbonic acid; the carbonate of soda runs out at the bottom of the tower, whilst the sulphuretted hydrogen and carbonic acid gases pass upwards through a tower filled with peroxide of iron in porous masses. The sulphur is there deposited upon the oxide of iron, and the mass only needs burning in the ordinary pyrites-kilns to yield sulphurous acid again. The numerous plans proposed for regaining the sulphur from the alkali-waste have also all proved abortive; nor indeed is this to be wondered at when we consider the mechanical difficulties of dealing with a mass of material amounting in some works to 600 tons weekly, and when we likewise remember that the waste contains only from 15 to 20 per cent. of sulphur, which, if it could all be easily extracted, would only make the mass worth about 15*s.* per ton.

The improvements of detail effected in the soda-manufacture since the year 1851 have mainly been the following:—

(1) Greater attention to economical working in all the branches than was formerly given, especially in the burning of pyrites, and in the evaporation of the black-ash liquors, which is now wholly effected by the waste heat from the black-ash furnaces. The arrangement for the evaporation of the black-ash liquors by means of the spent heat of the black-ash furnaces was proposed by Mr. Gamble of St. Helens, and by him liberally presented to his co-manufacturers.

(2) The process of lixiviation of the black ash is more completely accomplished than formerly by the employment of the very ingenious and simple arrangement originally proposed by Mr. Shanks, and by him given to the soda-trade. According to Mr. Shanks's method, all pumping of the liquors or handling of the black ash is avoided, a much more perfect abstraction of the soluble constituents is gained, and a great saving in expense of evaporation is effected.

(3) In some works the black ash is now made by machinery, under a patent granted to Messrs. Elliot and Russell in 1853, and more recently improved by Messrs. Stevenson and Williamson of the Yarrow Chemical Works, Newcastle. In this method the mixture of salt-cake, coal, and limestone is introduced into revolving iron cylinders, lined with firebricks, and heated by a furnace, so that thus the process of manual stirring is avoided.

(4) The soda-ash is now in many alkali-works packed into casks by machinery.

Since the year 1851 an entirely new branch of the manufacture has been introduced by the preparation of solid caustic soda, an article now largely exported to America and other localities, to which carriage is expensive.

In the preparation of solid caustic soda advantage is taken of the facts, that in all the black-ash liquors nearly one-third of the total alkali is present as the hydrate, and that on concentrating these liquors by boiling, the whole of the carbonate, and the greater part of the chloride, sulphate, and other neutral salts separate, and may be removed by mechanical means, leaving in solution the caustic alkali with a small quantity of sulphides and cyanides which are oxidized by nitrate of soda, as afterwards described. Sometimes, however, it is found convenient to causticize with lime the whole of the black-ash liquor before evaporation : the caustic alkali must then be prepared in a dilute solution ; otherwise, as is well known, a complete decomposition does not occur. In order to utilize the heat wasted by the necessary evaporation of the lye, Mr. Dale has patented a plan for boiling down the caustic liquors in closed iron boilers, employing the steam for motive power or for heating purposes. Mr. Dale finds that the liquors may be thus concentrated to sp. gr. 1·30 without in any way injuring the boilers. When the lye has obtained the above strength, it is concentrated in open iron pans, and nitrate of soda is added to oxidize the sulphides and sulphites, large quantities of ammonia being evolved. As soon as the greater portion of the uncombined water has gone off, and the mass begins to undergo igneous fusion, the cyanides are decomposed by the nitrate—nitrogen and oxygen gases being liberated, and the carbon of the cyanogen appearing as a crust of finely divided graphite. This interesting fact of the production of graphite by decomposition, probably, of the cyanides, was first observed by Dr. Pauli of the Union Alkali-works of St. Helens. The caustic soda thus prepared is often perfectly white, although generally of a greenish colour from traces of manganese; it contains neither iron nor alumina, the former being precipitated as an insoluble anhydrous peroxide, and the latter separating out as a crystalline alkaline silicate of alumina.

In concentrating the strong lye, the manufacturers were much troubled by the continual boiling over of the fusing mass, but this has been remedied by an ingenious application of the "Geyser" principle, also used in the kiers employed in bleaching cotton goods, which we saw in operation at Messrs. Gaskell and Deacon's Works at Widnes. At the bottom of the round pan in which the evaporation is conducted is placed a conical pipe of sheet iron, open at both ends, and reaching about an inch above the level of the fusing mass. This tube does not rest close to the bottom of the pan, openings being left for the entrance of the liquid. In contact with the heated iron, steam is formed at the bottom of the tube, and the liquid is thus forced out at the top of the tube, preventing altogether any violent ebullition occurring in the other part of the pan, and consequently effectually stopping the boiling over of the fused mass.

The proposition recently made by Kuhlmann for the employment of the alkali-waste as a cement is not new, Mr. Deacon of Widnes having used this waste material for making floors twelve years ago.

The investigations of Mr. Gossage on the constitution of black ash have been the base of a very important branch of that manufacture. This gentleman, so long ago as 1838, expressed his doubts as to the correctness of the view taken by Dumas and other chemists concerning the composition of the black ash, namely, that the separation of the soluble carbonate of soda from the compounds of sulphur and lime by treatment with water depends upon the formation of an insoluble oxysulphide of calcium. Mr. Gossage showed that in all the liquors obtained by dissolving the black ash nearly one-third of the total quantity of alkali is present as caustic soda, and that this closely corresponds to the excess of caustic lime practically employed, whereas in the dry substance no caustic soda can be dissolved out by alcohol. Hence he concluded that the black ash consists of a mixture of carbonate of soda, caustic lime, and monosulphide of calcium, and that when the mass is treated with water, caustic soda and carbonate of lime are formed, the monosulphide of calcium itself being insoluble in water. This theory of the composition of black ash is now generally adopted by chemists practically engaged in alkali-making, and has received confirmation by the subsequent analyses of Mr. F. Claudet and others.

The growth of the soda-ash manufacture has been so rapid, and so many changes have been caused by it in the chemical arts, that a short sketch of its history may with great propriety be added to this portion of our subject—this sketch being in the main an abridgement of Mr. Gossage's paper read before the Section. Previous to 1793, soda was made almost entirely from the ashes of sea-weed obtained from Alicante, Sicily, Teneriffe, Scotland, and Ireland. Potash from Russia, France, and America supplied its place to a large extent; now, however, soda supplies the place of potash, even in those countries from which we formerly obtained potash. In 1794 a French Commission decided that Leblanc's soda-ash process was the best proposed. The Government made it known to the public in 1797. The inventor died in poverty; but many manufacturers rose up in France and obtained great success. It was little known in this country till 1823, when the duty of £30 a ton was taken off salt.

In connexion with soda, muriatic acid and chlorine must be named. Although Scheele, a Swede, discovered chlorine, Berthollet discovered its bleaching properties. The process was introduced into Scotland by Professor Copeland of Aberdeen; and in 1798 Mr. Charles Tennant of Glasgow patented a solution of chloride of lime as a bleaching-liquor, which was followed up by the invention of the present bleaching-powder. When common salt is decomposed by sulphuric acid, the muriatic acid from which the chlorine is obtained is set free; when this process was performed by bleachers the duty on the salt was remitted, but they were compelled to throw away all the sulphate of soda formed—a strange and most wasteful act. This continued till 1814. About this time occurred the expiration of Tennant's patent for bleaching; and crystals of carbonate of soda were gradually introduced at £30 per ton. Mr. Losh, of Newcastle, had made use of Leblanc's process almost from its publication, but on a small scale. In 1802 he sold soda-crystals at £60 per ton; the present price is £4 10*s*. But in 1823 may be dated the commencement of the soda-ash manufacture in this country, when Mr. James Muspratt erected his works at Liverpool.

The decomposition of the salt was made chiefly in open furnaces; so that an enormous amount of muriatic acid was sent into the air, and soda-works were removed from towns when the Woulfe's apparatus was not used for condensation. To remedy this loss, Mr. Gossage invented, in the year 1836, the coke tower as at present used. The acid gases percolate through a deep bed of coke, which fills a high tower, and which is supplied with water trickling through the porous material. Mr. Gossage and Mr. Shanks are said to have so purified the gas at Messrs. Crossfield's works at St. Helens, that it did not even render a solution of nitrate of silver turbid.

In 1838, when the King of the Two Sicilies monopolized the trade in sulphur, it was raised in price from £5 to £14 per ton, when the Irish pyrites began to be used. This again led to the extraction of the copper from the spent pyrites, and also of the silver, a process commenced by Mr. Gossage in 1850. Mr. John Wilson began to extract the gold, but without commercial success.

Since Mr. Muspratt began his works the price of soda has been reduced 60 per cent., although the raw materials have fallen only 10 per cent.

There are about fifty soda-works in Great Britain; and the following amounts are made, as far as is known:—

3000 tons of soda-ash per week.
2000 tons of soda-crystals per week.
250 tons of bicarbonate of soda per week.
400 tons of bleaching-powder per week.

About 10,000 persons are employed in these operations, exclusive of those engaged in procuring salt, coal, pyrites, and limestone, and in the transportation of the materials.

The new French Treaty reduces the import duty into France 15 per cent., or 36*s*. per ton. At the time of making the Treaty, it was estimated that 59,000 tons of salt were used in France for soda, and 260,000 in Great Britain.

The following Table gives the amount of materials used at present for the production of 1 ton of soda-ash, and their prices:—

	£	*s.*	*d.*
$1\frac{1}{4}$ ton of Irish pyrites	1	15	0
1 cwt. nitrate of soda	0	12	0
$1\frac{1}{4}$ ton of salt	0	10	0
$1\frac{1}{4}$ ton of limestone	0	10	0
$3\frac{1}{4}$ tous of fuel	1	1	0
	£4	8	0

Chronology of the Soda Trade.

Period.	Raw Materials used and Prices.	Quantity manufactured.	Prices.
1790	Barilla and Kelp.	Not known.	Not known.
1792	Leblanc's process invented and applied in France.	Not known.	Not known.
1814	Crystals of soda, made from bleacher's residua, and by Mr. Losh from brine.	Not known.	Soda-crystals £[illegible]0 per ton.
1823 and 1824	Mr. Muspratt's Works commenced, using— Common salt at ....15*s*. per ton. Sulphur at ....£8 per ton. Lime at......................15*s*. per ton. Coal at ....8*s*. per ton.	Probably 100 tons per week of crystals and soda-ash.	Soda-crystals £18 per ton. Soda-ash £24 per ton.
1861	50 works in operation in Great Britain, using Leblanc's process, raw materials in Lancashire costing, Common salt ....8*s*. per ton. Sulphur from pyrites.......£5 per ton. Limestone..................6*s*. 8*d*. per ton. Fuel ....6*s*. per ton.	5000 tons per week.	Soda-crystals £4 10*s*. per ton. Soda-ash £8 per ton.

III. Bleaching-Powder.

In some alkali-works the waste hydrochloric acid is employed to evolve carbonic acid from limestone for the manufacture of bicarbonate of soda from soda-crystals; in others the acid is used for the preparation of bleaching-powder and bleaching-liquor, both of which products are made in large quantities in the district, 155 tons of bleaching-powder* being made each week.

The only points in this manufacture which call for remark are:—

(1) An ingenious process for preparing chlorine without the use of binoxide of manganese is used by Mr. Shanks of St. Helens. The process is as follows:—Hydrochloric acid is added to chromate of lime, sesquichloride of chromium and free chlorine are produced, and the free chlorine is used for making bleaching-powder. Then lime is added to the sesquichloride of chromium, and the precipitated sesquioxide reconverted into chromate by heating with lime in a reverberatory furnace.

(2) The regeneration of peroxide of manganese from the waste liquors containing chloride of manganese has, as is well known, been performed with success by Mr. Charles Dunlop, so much so that the product obtained is almost pure. Dr. Gerland of Newton-le-Willows has communicated to us the following process for recovering from these liquors not only peroxide of manganese, but also the nickel and cobalt which they contain. The liquors are first neutralized with limestone, and then caustic lime is added until all the iron is precipitated as hydrated peroxide of iron. The precipitate, after washing and drying, may be used as yellow ochre. The filtrate contains manganese, nickel, and cobalt. The two latter metals are precipitated as sulphides by means of a solution of sulphide of calcium (obtained from black-ash waste), which is added until the precipitate ceases to be of a pure black. The precipitate is now collected and subjected to the well-known manipulations for separating the metals. The supernatant liquid is siphoned off, and the manganese contained in it is precipitated as hydrated protoxide by adding milk of lime. The oxide is washed by decantation and thrown on calico for draining. It is converted into the higher oxide simply by the agency of heat and air, and is generally obtained as a fine black powder containing 70 per cent. of peroxide. The average quantity of cobalt contained in 1 ton of manganese is 10 lbs., and of nickel 5 lbs.

IV. Chlorate of Potash.

From 4 to 5 tons of this salt are manufactured weekly in this district. It is employed for making matches, and also as an oxidizing agent in steam colours on calico.

V. Hyposulphite of Soda.

This salt is manufactured by Messrs. Roberts, Dale and Co., to the extent of 3 tons weekly. It is prepared by passing sulphurous acid through a solution of sulphide of sodium, and purified by recrystallization. It is used by paper-makers, by photographers, and by bleachers (known as antichlor).

VI. Silicate of Soda.

The experiments of Fuchs, Kuhlmann, and others have shown that the alkaline silicates may be employed with success for the purpose of coating building-stones of a soft or porous nature, thus enabling them to resist the action both of air and water. Another use has been found for them in this district, viz. as a substitute for cow-dung in calico-printing; and they are also extensively employed by soap-manufacturers in place of the resinates. Silicate of soda is the compound employed. The process of manufacture is simple. Sand and carbonate of soda are melted together, a sufficient quan-

* Of this quantity 70 tons are produced at St. Helens, 40 at Runcorn and Runcorn Gap, and 45 in Flint.

tity of the latter being taken to prevent the watery solution afterwards gelatinizing. The product has the appearance of glass, transparent in thin layers, and variously coloured in mass, from pale yellow to brown or black, the colour being due to the presence of carbon. Occasionally it is of a pale green. As it is difficult to reduce it into fragments by pounding, on account of its extreme brittleness, it is found advantageous to allow the fused mass to run directly into water, by which means it is immediately broken up into pieces of a convenient size. About 10 tons per week are produced in this neighbourhood.

VII. Arseniate of Soda.

This salt has of late come into very general use as a substitute for cow-dung in calico-printing, for which purpose it is much better adapted than the phosphate or silicate of soda, as it does not attack the alumina mordants to so great an extent as those salts. It is generally prepared by fusing arsenious acid with nitrate of soda and caustic soda. Without the addition of caustic soda, an acid arseniate would be formed. In this way, however, a considerable loss of arsenious acid takes place. Mr. Higgin, of this city, has therefore invented and patented a process, by which this loss is prevented. He dissolves the arsenious acid in caustic soda, adds nitrate of soda, introduces the mixture into a reverberatory furnace, and allows the heat of the fire to pass over the surface. In the first instance ammonia is given off, then nitric oxide. The heating is continued until the paste is perfectly dry. This process is attended by a saving, not only of arsenious acid, but also of nitrate of soda. The advantages attending the use of arseniate of soda for dunging are, that a greater proportion of the mordants becomes fixed, and that the colours are superior and the whites purer after dyeing than with other materials. Its use is also attended with greater economy. It is to be regretted that so valuable a substance as this should also be one of so highly poisonous a nature.

The quantity produced in this district amounts to 10 or 12 tons per week.

VIII. Bichromate of Potash.

We have nothing new to report regarding the manufacture of this salt. About 14 tons are produced weekly in our district.

IX. Prussiates of Potash.

From 4 to 5 tons of yellow prussiate of potash and 1 ton of red prussiate are produced in this district per week.

X. Superphosphate of Lime.

Weekly production in this district, 500 to 600 tons.

XI. Sulphate of Baryta.

Of this salt, which is usually sold under the name of "blanc fixe," about 2 tons are made in this district by precipitation. The plan pursued is very simple: Derbyshire heavy spar is heated with carbon, the sulphide of barium thus obtained is decomposed with muriatic acid, and from the solution the baryta is precipitated as sulphate. When prepared in this manner, it is found to be better adapted for the purpose to which it is applied than the ore simply ground, as it possesses more body as a paint than the latter.

XII. Epsom Salts.

Weekly production in this district, 20 tons.

XIII. Alum.

One of the most important improvements introduced into our chemical manufactures during the last twenty years is the new process of making alum, first patented by Mr. Spence in 1845, and carried out on a large scale by Messrs. Spence and Dickson since 1847. Before that time the alum manufactured in this district was confined to a small quantity made from pipeclay, our chief supplies being derived from Whitby. By the old process, 60 tons of the oolitic shale of Yorkshire were required in order to produce 1 ton of potash alum and 1 ton of Epsom salts. By Mr. Spence's process 50 tons of shale yield 65 tons of ammonia-alum. Mr. Spence employs the shale found underlying the seams of coal in this district. This shale, which is black from the organic matter contained in it, is piled up in heaps about 4 or 5 feet high, and slowly calcined at a heat approaching to redness. Before calcination the alumina of the shale will not dissolve in sulphuric acid; and, on the other hand, if the heat be raised too high, so as to induce a partial vitrification of the clay, the alumina is again rendered quite insoluble in acid. The calcination lasts ten days, the heaps being supplied daily with fresh shale. When sufficiently calcined, the material is soft and porous, and of a pale brick-red colour. The calcined shale is then placed in covered pans, each capable of holding 20 tons of the material, and is there digested from thirty-six to forty-eight hours with sulphuric acid of sp. gr. 1·35. The liquid is kept at a temperature of 230° Fahr., partly by fire underneath the pans, and partly by the introduction of vapour from a boiler containing gas-liquor. This part of the process was patented by Mr. Spence in 1858–59, it having been found unnecessary to treat first with acid and then with alkali, the combined treatment answering quite as well, provided there is an excess of acid present. The volatile ammonia-salts of the gas-liquor pass over into the pans and are decomposed by the acid; the ammonia of the remainder is liberated by the addition of lime. The liquor is now run off into cisterns, and kept continually agitated while it cools, in order to promote the formation of small crystals. The crystals are allowed to drain, and washed with the liquor which runs off from the blocks of alum. No iron is found in the crystals, though there is an abundance in the mother-liquor in the shape of persulphate of iron. To this succeeds the so-called *Roching* process, which simply consists in rapidly recrystallizing. This is effected by Mr. Spence through the agency of steam, without the addition of water. The crystals are thrown into a hopper, at the bottom of which they come into contact with a current of steam, which dissolves them rapidly, fresh crystals being successively added in quantities sufficient to prevent the escape of the steam. By this means 4 tons of crystals may be dissolved in one half to three quarters of an hour. The solution runs immediately into a leaden tank, where it is allowed to settle for three hours, and deposits a quantity of matter insoluble both in water and acid, supposed to be a compound consisting of, or containing subsulphate of alumina. The clear liquor is now allowed to run into tubs, the bottoms of which are formed of Yorkshire flags each 6 feet in diameter, and the sides of moveable staves 6 feet long, which are kept in their places by hoops and screws. After standing from five to eight days, the hoops are unscrewed and the staves removed, when a mass of crystallized alum of the form of the tub appears. After standing eight days longer, a hole is made at 8–10 inches from the bottom, and a quantity of liquor runs out. The mass is generally 18 inches thick at the bottom, and 1 foot at the sides, and contains 3 tons of marketable alum, while the liquor contains 1 ton, which goes back to the pans.

In 1850–51, Mr. Spence made about 20 tons of alum per week. The quantity now made by him amounts to 110 tons, of which 70 tons are produced in this district. Fully half of the total quantity manufactured in England (300 tons per week) is made by his process.

XIV. Protosulphate of Iron.

This salt is manufactured in large quantities in this district, principally for the use of dyers, the amount being about 80 tons per week. The process of manufacture pursued here is as follows:—Iron pyrites, derived from the coal-measures, and commonly called here *coal brasses,* is piled up in heaps, watered and exposed to the atmosphere. A process of slow oxidation takes place. Sulphate of iron with an excess of sulphuric acid is formed. The latter is removed by means of scrap iron. The salt is obtained by evaporation of the liquor, and is tolerably pure. An inferior quality is procured from the mother-liquor, which contains alumina.

XV. Compounds of Tin.

Chlorides of Tin.—The quantity of these compounds (estimated as crystallized protochloride of tin) manufactured in this district amounts to about 16½ tons per week.

Stannate of Soda.—This compound has for some time been extensively used for the purpose of preparing calicoes which are intended to be printed with so-called steam colours. It is usually obtained by fusing metallic tin or finely powdered tin ore with nitrate of soda. It has been found that the addition of 5 per cent. of arseniate of soda causes a saving in tin, by rendering, as it seems, the oxide of tin less soluble in the sulphuric acid, through which the goods are subsequently passed.

Stannate of soda is also prepared from scrap tin by Mr. Higgin's process. Various attempts, with more or less success, have been made at various times to separate the tin and the iron of scrap tin, or waste tinned iron, and so utilize the former metal. Mr. Higgin acts on the scrap with a mixture of muriatic acid and a little nitrate of soda. When muriatic acid is used alone, the iron dissolves more rapidly than the tin, but when nitrate of soda is added, the tin is acted on in preference. The whole of the nitrate of soda disappears, and the resulting products are bichloride of tin, chloride of ammonium, and chloride of sodium, in accordance with the following equation:

$$4\,Sn + 10\,Cl\,H + Na\,NO_6 = 4\,Sn\,Cl_2 + NH_4\,Cl + Na\,Cl + 6\,HO.$$

The bichloride of tin is then converted, by the excess of tin present, into protochloride. A little iron dissolves at the same time and is separated by means of chalk, which precipitates the protoxide of tin, leaving the iron in solution. The former is then converted, by fusion with nitrate of soda and caustic soda, into stannate of soda, with evolution of ammonia. The iron stripped of the tin is employed for the precipitation of copper.

XVI. Copper Ores.

Mr. William Henderson has introduced into this district a mode of dealing with very weak copper ores, which has been found extremely successful at Alderley, where the sandstone contains only 1¼ per cent. of copper, in the form of carbonate and arseniate. The sand containing the copper is put into wooden vats with muriatic acid, and fresh sand added until the amount of copper is sufficient for saturation. The solution is then drawn off, and the copper precipitated by waste or *scrap* iron. In this way ores otherwise useless have become valuable.

Another mode of attaining this object, and one in many cases to be preferred, is by using sulphuric acid and boiling down the solution of sulphate of copper so as to obtain crystals, or still further, viz. to dryness. This is then heated in a furnace having a plate, or floor, of brickwork or tiles, the fire being applied beneath, and not passing over the salt of copper: the sulphate is decomposed, and sulphuric acid passes off. But the decomposition is more effectual when carbon is added; in this way sulphurous acid is driven off, and it is then led into a chamber, and being treated with nitrous fumes in the usual way, sulphuric acid is formed, which is again used for the solution of the copper in the ore. If the ore contains suboxide of copper, it is previously roasted for oxidation. Phosphates, arseniates, carbonates, and oxides may be treated by this process.

For sulphides of copper Mr. Henderson roasts with common salt, having previously reduced the ore to fine powder. The chloride of copper is volatilized and condensed in a Gossage coke tower. The sulphate of soda remaining may be washed out of the non-volatile portion, and the copper precipitated from the solution flowing from the tower. He separates by this means the metals whose chlorides have a different rate of volatilization: chlorides such as chloride of silver are obtained in the flue close to the furnace.

We do not allude to the other inventions contained in Mr. Henderson's patents, as we are not aware of any being in use in this district.

XVII. Nitric Acid.

About 48 tons of nitrate of soda per week are used in this district for making nitric acid. The salt yields its own weight of acid of sp. gr. 1·40. Nitric acid is used here for making the nitrates of copper, lead, alumina, and iron, for oxidizing tin, for etching, and also for making aniline from benzole.

XVIII. Oxalic Acid.

One of the most important and most interesting of the new manufacturing processes which we have to describe in this Report is one for the preparation of oxalic acid, invented and patented by Messrs. Roberts, Dale and Co., gentlemen to whom we owe a number of highly ingenious and useful practical processes. The method of preparing oxalic acid hitherto employed consists, as is well known, in acting on organic substances, such as sugar or starch, with nitric acid. This process has now been superseded by that of Messrs. Roberts, Dale and Co., which depends on the action exerted by caustic alkalies on various organic substances at a high temperature. That oxalic acid is one of the products formed by this action is a fact well known to chemists, but one that has not until recently been turned to any practical use. In the year 1829, Gay-Lussac published a short memoir*, in which he announced that he had succeeded in obtaining oxalic acid by heating cotton, sawdust, sugar, starch, gum, tartaric acid, and other organic acids with caustic potash in a platinum crucible. Since that time the subject has not been attended to either by scientific chemists or by practical men, so far as we know. Messrs. Roberts, Dale and Co. are, we believe, the first persons who have succeeded in carrying out the process in practice on a large scale. In their attempt to do so they were met by a number of serious obstacles, chiefly of a practical nature. These, however, they have, by dint of uncommon ingenuity, and by the application of an amount of perseverance of which, perhaps, but few men are capable, succeeded in

* Annales de Chim. et de Phys. t. xli. p. 398.

overcoming, and the process is now in full and successful operation at their works at Warrington. With a most praiseworthy liberality, these gentlemen have furnished us with full particulars regarding their process. They have also allowed us to see it in operation, and we are therefore able to lay before the Section all the details necessary for becoming acquainted with its principal features.

The only practical suggestion contained in Gay-Lussac's memoir, consists in his proposal to convert cream of tartar by this method into oxalate of potash. At that time tartaric acid was cheaper than oxalic acid, and the suggestion might therefore, under the circumstances of the time, have proved of some practical value. It was evident, however, that for the purpose of ensuring success a cheaper material had to be chosen. Messrs. Roberts, Dale and Co. found woody fibre in the shape of sawdust to answer perfectly. Gay-Lussac states, as the result of his experiments, that potash may be replaced by caustic soda. Mr. Dale found, however, that woody fibre produces hardly any oxalic acid with caustic soda. On the other hand, when potash is used alone, the process is not remunerative. This difficulty was overcome by employing a mixture of soda and potash, in the proportion of two equivalents of the former to one of the latter, which produces the desired effect quite as well as potash alone. In what manner the soda acts in this case can only be conjectured: whether in conjunction with the potash it takes the place of the latter, or whether it merely promotes the fusibility of the mixture, is merely a matter for speculation. The solution of the mixed alkalies having been evaporated to about 1·35 sp. gr., sawdust is introduced, so as to form a thick paste. This paste is then placed on iron plates in thin layers and gradually heated, the mass being kept constantly stirred. During the heating-process, water is in the first instance given off. The mass then swells up and disengages a quantity of inflammable gas, consisting of hydrogen and carburetted hydrogen. A peculiar aromatic odour is at the same time evolved. After the temperature has been maintained at 400° Fahr. for one or two hours, this part of the process may be considered as complete. The whole of the woody fibre is now decomposed, and the mass, which has a dark-brown colour, is entirely soluble in water. It contains, however, only from 1–4 per cent. of oxalic acid, and about 0·5 per cent. of formic, but no acetic acid. What the nature of the principal product intermediate between the woody fibre and the oxalic acid is has not yet been determined; it seems well worthy of further investigation. The mass is now exposed still longer to the same temperature, care being taken to avoid any charring, which would cause a loss of oxalic acid. When perfectly dry, it contains the maximum quantity of oxalic acid, viz. from 28–30 per cent. (C_2O_3+3HO), but still no acetic acid, and very little more formic acid than before. The absence of acetic acid is surprising, as it is generally supposed to be an essential product of this process of decomposition. It is possible that the acetates may be converted into oxalates as they are formed; but, on the other hand Gay-Lussac states that acetates when heated with caustic alkalies yield chiefly carbonates, and but a trifling proportion of oxalates—a conclusion to which Mr. Dale has also been led from direct experiments with acetates*.

The product of the heating-process, which is a grey powder, is in the next place treated with water heated to about 60° Fahr. In this the whole dissolves, with the exception of the oxalate of soda which is either contained in it, or is formed by double decomposition on the addition of water, and which, on account of its slight degree of solubility, falls to the bottom. The use of the

* It may be mentioned that the process of decomposition takes place equally well in close vessels. It must therefore be accompanied by a decomposition of water.

soda in this part of the process is sufficiently apparent. The supernatant liquid is drawn off and evaporated to dryness, and the residual mass is heated in furnaces in order to destroy the organic matter and recover the alkalies which it contains, and which are employed again after being causticized for acting on fresh sawdust. In consequence of the elimination of soda, the relative proportion of the two alkalies recovered from the liquor is, of course, different to what it was at the commencement; and before being used again the quantity of each alkali contained in the mixture must be ascertained.

The oxalate of soda, after being washed, is decomposed by boiling with hydrate of lime. Oxalate of lime falls to the bottom, and caustic soda passes into solution, and may be employed again for any purpose to which it is applicable. The resulting oxalate of lime is decomposed by means of sulphuric acid, the proportions employed being three equivalents of acid to one of the oxalate; and the liquor decanted from the sulphate of lime is evaporated to crystallization in leaden vessels. The crystals of oxalic acid, which are slightly coloured by organic matter, are purified by recrystallization.

From about 2 lbs. of sawdust 1 lb. of crystallized oxalic acid may be obtained. There is no loss of oxalic acid. The only loss experienced is in alkalies. The quantity of acid at present manufactured by Messrs. Roberts, Dale and Co. amounts to 9 tons per week; and their works are capable of being extended so as to produce 15 tons, which is supposed to be the total quantity consumed throughout the world. Their plant is extensive and costly, and bears evidence of an uncommon spirit of enterprise on the part of the proprietors.

In order to give an idea of the effect which the introduction of this process has had on the market, it may be mentioned that the selling price of the acid at this time is 8*d.* to 9*d.* per lb., whereas in 1851 it was 15*d.* to 16*d.* per lb.

Oxalic acid is used extensively in calico-printing, woollen-dyeing, woollen-printing, silk-dyeing with wood colours, in straw-bleaching, and for making binoxalate of potash, the so-called "salt of lemons."

XIX. Pyroligneous Acid.

The only improvement introduced into the manufacture of this acid during the last few years consists in the use of sawdust instead of wood in the process of destructive distillation. The sawdust is introduced into the front of the retort through a hopper, and is gradually moved to the other end by means of an endless screw, worked by machinery. During its transit it becomes completely carbonized, the gaseous and liquid products escape through a pipe, while the charcoal is allowed to fall into a vessel of water. The latter precaution is necessary, since the carbon is obtained in such a minute state of division that no cooling in the air or in closed vessels would be sufficient to stop the combustion. In other respects the process does not differ essentially from that with wood. No more acid is obtained than with wood, and less naphtha. The quantity of the former varies, however, with the temperature employed. The usual temperature is that of a dull red heat. From 1 ton of sawdust 100–120 gallons of liquid, containing 4 per cent. of glacial acid and 15 gallons of tar, are obtained, and 100 parts of the crude distillate yield 3 of naphtha. The advantage consists in the cheapness of the material employed; but, on the other hand, one of the resulting products, viz. the finely divided charcoal, is comparatively worthless.

This invention forms the subject of Mr. Halliday's patent, which was taken out in the year 1848–49. Quite recently Mr. Bowers has patented another plan, which consists in passing the sawdust into the retorts by means of an inclined plane, and a series of scrapers.

Quantity of acid manufactured weekly in Manchester:—12,000 gallons, containing about 4 per cent. of glacial acid.

The value of the acid is £3 per ton, whilst that of the tar is from £4 to £4 10*s*.

The quantities of *red liquor* (acetate of alumina) and *iron liquor* (protacetate of iron) made may be stated here, as they are always made by means of pyroligneous acid, and generally by the same parties who manufacture the acid. Red liquor, 12,000 gallons. Iron liquor, 6000 gallons.

XX. Starch and Artificial Gums.

About 20 tons of starch and 34 tons of gum-substitutes, made by roasting farina and other kinds of starch, are produced in this district per week.

No change has taken place in the process of manufacturing starch from flour. The old process of fermentation is still adhered to.

XXI. Purification of Resin.

Several very interesting and successful processes have lately been patented by Messrs. Hunt and Pochin of Salford, for the purification of resin. The aim of these gentlemen, who have devoted a large amount of time and attention to this subject, is to produce a bright, nearly colourless, solid and brittle resin from the common dark and impure commercial article. This end they attain by distilling the resin in an atmosphere of steam at about 10 lbs. pressure. The several resinous acids which on distillation by themselves split up into gaseous products and volatile oils of very variable composition, are mechanically carried over, it would appear, in presence of steam, as is well known to be the case with stearic and the other higher fatty acids; and a solid product, which cannot be distinguished from the finest resin, is obtained from a very impure material. In their patent of 1858, Messrs. Hunt and Pochin specify the formation of three distinct solid products during different stages of the process; these they distinguish as α, β, and γ resin. These three several substances present the characteristics of resins, but clarified and to a great extent deprived of colour. They are either separately or in combination applicable to and useful in the manufacture of several important articles, such as soap, size, candles, paper-size, varnish, and japan; and they may be used for distilling to produce resin-oils.

About 60 tons per week of this purified resin are now manufactured in this district under this patent.

XXII. Organic Colouring-Matters.

There are few substances of more importance to the manufacturers of this district than those which are employed in imparting colour to the various fabrics, especially those of cotton, produced here. Of these substances the majority are derived from the animal or vegetable kingdom. Indeed, with the exception of oxide of iron and chromate of lead, very few mineral substances are at the present time made use of alone by the dyer or printer. The greater intensity, beauty, and variety of the dyes which are wholly or in part composed of organic matters causes them to be preferred; and the increase of skill and knowledge of scientific principles on the part of dyers and printers has also led to their more exclusive employment. When it is stated that the quantity of dye-woods (logwood, peachwood, sapanwood, barwood, fustic, quercitron bark) consumed weekly by the dyers of this district amounts to 300 or 400 tons, that the weekly consumption of the same by printers is about 60 tons, that from 150 to 200 tons are in the same time converted into extracts, and that 150 tons per week of madder are used up, exclusive of what is used for garancine, &c., some idea of the magnitude of the interests depending on the employment of these materials may be formed.

The chemistry of colouring-matters is still in its infancy. Indeed, so few of them have as yet been prepared in a state of purity, that we have hitherto been able merely to lay down a few general principles applicable to all. The direct applications of science in this branch of the arts are therefore few. The purely practical improvements which have been introduced in dyeing and printing within the last twenty years are, however, numerous and important. Among these may be mentioned the invention of steam colours, which certainly dates from an earlier period, but has of late years received a much more extensive application—the improved methods of preparing extracts of dye-woods—the fixation of insoluble pigments on fabrics by means of albumen—the introduction of artificial colouring matters, such as murexide, and the various colours from aniline.

In the present Report we must, however, confine ourselves to the improvements which have been made in the preparation of the materials used for the purpose of dyeing, without entering into the subject of the dyeing-processes themselves.

No dyeing-material has received so much attention, both on the part of scientific chemists and of practical men, as indigo. The chemical properties of its most important constituent have been fully investigated, and its behaviour when applied in practice carefully examined. It is perhaps on this very account that we find nothing of importance to report under this head. With the exception of a new method of reducing indigo by means of finely divided metals, patented by Leonard, we do not suppose that any important improvement has been introduced in connexion with this dye-stuff.

Of no less importance in the art of dyeing is madder, the material with which the most permanent reds, purples, and blacks are produced. The methods which have been proposed for more effectually utilizing this important dye-stuff are very numerous indeed, though exceedingly few of them have been found to be of practical value. They may be divided into two classes, viz., those having for their object to render available the greatest amount of colouring-matter, and those which tend to produce more permanent or more beautiful colours. The first object seems to be perfectly attained by converting the madder by the action of acid into *garancine.* This preparation is becoming more and more extensively used. There are printing-establishments in which nothing else is employed in the production of madder colours. Even in turkey-red dyeing it is beginning to be much used, thus proving the fallacy of the opinion formerly entertained, that no preparation of madder could be made to supply the place of the crude material in this process. The garancine for this purpose is manufactured in Holland. It is said to be made by treating the roots with dilute sulphuric acid containing 35 per cent. of the weight of the madder of concentrated acid (the usual proportion in this country being about 25 per cent.), and boiling for several hours. By this means the pectic acid, one of the most hurtful constituents of the root, is removed. The residue left after the ordinary process of madder dyeing still contains a quantity of colouring-matter in a state of combination. By treating it with sulphuric acid a product is obtained called *garanceux,* which is again used for dyeing. The quantity of garancine manufactured in this district, exclusive of garanceux (which is mostly made and consumed by printers themselves), is estimated at about 1200 tons per annum, which would require about three times its weight of madder for its production.

Of the second class of inventions bearing on madder, perhaps the most successful is that which was patented by Pincoffs and Schunck in the year 1853. It is well known that in order to produce the finer descriptions of madder colours, such as pink and lilac, on cotton fabrics, it is necessary to subject the dyed goods to a long series of operations, such as soaping, aciding, &c. These processes are always attended with some risk of failure; and besides that, a very large quantity of madder (an excess, in fact) must be employed in dyeing, in order to obtain the ultimate effect desired. It is evident that, if the impurities (resins, pectine, &c.) accompanying the colouring-matters in the root could be removed or destroyed, the operations necessary after dyeing might be dispensed with or much curtailed, since the object of these operations is precisely the removal of these impurities from the dyed fabric. In the preparation of ordinary garancine a portion of these impurities is removed, but those which are insoluble, or difficulty soluble in water, remain behind for the most part, and subsequently exert a prejudicial effect in dyeing. Now the invention referred to above consists in subjecting garancine whilst in a moist state to the influence of an elevated temperature in close vessels (or what comes to precisely the same thing, to the action of high-pressure steam) for several hours. What takes place during this process is not exactly known. According to some experiments undertaken by one of us, it appears that the two red colouring-matters contained in madder, viz. alizarine and purpurine, are not in the least degree affected by it, whereas the pectic acid and some of the resinous colouring-matters are charred, and thus rendered insoluble and innocuous. Be this as it may, the result of the process is a product which, when used for dyeing, yields colours requiring very little after-treatment in order to give them the required degree of brilliancy, whilst they are quite as permanent as those produced by madder itself. The use of this material is attended by a saving in dye-stuff, mordants, and soap, as well as in time and labour. The results are also more certain. Moreover, when other colours, such as brown and orange, are introduced in combination with madder colours, the effect is much superior to that produced with madder, where the soapings required to yield the desirable brightness deteriorate the other colours. There are other advantages of a practical nature attending its use which need not be here referred to. It has, however, one disadvantage, viz. that from some unexplained cause it is not well adapted for dyeing pink; and for this colour it is therefore still necessary to employ unprepared madder. The product has obtained the name of *Commercial Alizarine*, since the effect in dyeing is similar to that of the pure colouring matter, alizarine. It is manufactured on a large scale by Messrs. Pincoffs and Co. Since its introduction in 1853, more than three million pieces of calico have been dyed with it in our district and in Scotland.

Mr. Higgin prepares commercial alizarine by boiling garancine with water, carbonate of soda, and a little ammonia. The liquid, which is alkaline at first, is boiled until it becomes acid. A short boiling gives a garancine adapted for dyeing purple, whilst a boiling of twenty-four hours yields alizarine.

We may here mention Messrs. Roberts, Dale and Co.'s process for preparing lakes, as the compounds of organic colouring-matters with various bases are usually called. Such lakes, with a basis of alumina, have for a long time been made from peachwood, sapanwood, and other dye-woods; but they had several disadvantages, which restricted their use in practice. They were not permanent, they had little body, and they were gelatinous and consequently cracked in drying. These disadvantages have been obviated by Messrs. Roberts, Dale and Co., who employ oxide of tin as a base instead of alumina, and produce lakes which, owing partly to their physical condition, and partly to their chemical composition, possess the requisite degree of permanency and intensity of colour. The lakes prepared by the above-mentioned firm are sold to the paper-stainers, who make use of them for the manufacture of a peculiar style of paper, called *mock flocks*, which form an excellent imitation of true flock papers, and are consequently used in large quantities.

Messrs. Roberts, Dale and Co.'s process for making a scarlet lake from barwood, which is peculiar, may be here shortly described. The colouring-matter of this wood is very slightly soluble in water. The ground wood is therefore simply treated with boiling water, to which the requisite quantity of precipitated oxide of tin is added. The boiling water dissolves some colouring-matter, which is immediately separated by the oxide of tin, and more colouring-matter then passes into solution to be precipitated as before, the process being continued until the compound acquires the requisite intensity of colour, and the wood is exhausted. The whole being now left to repose, the wood, which is heavier than the dyed oxide of tin, sinks to the bottom, leaving the pigment floating in the liquid. The latter is decanted off, passed through fine sieves to separate some woody fibre, and allowed to stand. The lake is deposited, and after being pressed is ready for use. The quantity of this lake manufactured weekly by this firm is 2 tons, and the price 8*d*. per lb.

The production of artificial colouring-matters for practical purposes has of late attracted much attention among scientific men and manufacturers. To this class of products belongs *Murexide*, a body which, as far as we know, does not occur ready-formed in nature. This substance, which was first discovered by Prout, and subsequently examined by Liebig and Wöhler, was until very recently unknown out of the laboratory of the chemist. This arose from the circumstance that uric acid, the only known source of murexide, has not until recently been found to occur anywhere in large quantities. The discovery of large beds of guano in various parts of the world has furnished us with a material containing a sufficient quantity, however small, of that acid to render the manufacture of murexide on a larger scale practicable; and it is now prepared in quantities surprising to those who have only seen it made on the small scale in the laboratory. The process pursued may be shortly described as follows:—The guano is first treated with dilute acid, in order to decompose the ammoniacal salts contained in it. The residue left by the acid is treated with caustic soda in order to dissolve the uric acid, and the solution, decanted from the insoluble portion (consisting of phosphates, sand, &c.), is supersaturated with muriatic acid. The precipitated uric acid is filtered off, washed with water, and dried, when it has the appearance of a brownish-white crystalline powder. The next part of the process consists in treating the uric acid with nitric acid. Measured quantities of the latter are poured into pots of about 1 gallon capacity, which stand in water for the purpose of being kept cool. A certain weight of uric acid is then introduced, in small quantities at a time, into each pot—a process which occupies about ten hours. The liquid has now a dark-brown colour, and is generally covered with a crystalline crust, consisting of alloxan and alloxantine. It may be remarked that the process does not succeed well unless both these substances are present—a fact already known from the researches of Liebig and Wöhler.

The liquid is then transferred to an enamelled vessel, diluted with water, and mixed with an excess of carbonate of ammonia when the object is to produce murexide or purpurate of ammonia. Generally, however, carbonate of soda is used, and in this case the product is purpurate of soda. The precipitated murexide or purpurate of soda is separated by filtration, washed and dried. It has the appearance of an amorphous, puce-coloured powder. The quantity manufactured by Mr. Rumney, of Manchester, amounted at one time to 12 cwt. per week, for which about 12 tons of guano were required. The price was at first 30*s.* per lb., but has now fallen to 15*s.* In printing cotton goods with murexide, nitrate of lead is used as a solvent, the solution properly thickened is printed, and the goods are then passed through a bath of corrosive sublimate. Other methods are employed, but they all depend on the use of salts of lead and mercury. The colour produced by murexide is so brilliant as almost to justify the belief entertained by Liebig and Wöhler, that the celebrated Tyrian purple of the ancients was obtained by its means.

XXIII. Aniline Colours.

The artificial colouring-matters from aniline and other bases have of late attracted much attention, and various plans have been devised for producing them. The usual method of obtaining aniline-purple, the so-called "Mauve," consists in submitting salts of aniline in watery solution to the action of oxidizing agents, such as chromates or permanganates, or the peroxides of manganese and lead. To these processes we may add another, patented by Messrs. J. Dale and A. Caro, and carried out in practice by Messrs. Roberts, Dale and Co. This process is based upon the fact that salts of aniline, when heated with solutions of perchloride of copper, completely reduce it to the state of protochloride, with the simultaneous formation of a black precipitate containing aniline-purple. Messrs. Dale and Caro dissolve one equivalent of a neutral salt of aniline in water, and boil this solution during several hours with a mixture of copper salts and alkaline chlorides corresponding to 6 equivalents of perchloride of copper. After the reaction is completed the mixture is filtered, the black precipitate well washed and dried, and afterwards extracted repeatedly with dilute alcohol in order to dissolve out the colouring-matters, which it contains in a remarkably pure state. These manufacturers have also produced aniline-reds by heating anhydrous hydrochlorate of aniline with nitrate of lead at 360° F. The product of this reaction is a bronze-like brittle mass, which contains aniline-red, always accompanied by purple colours. Boiling water extracts the red colouring-matters and separates them from the purple dyes, which after some purification constitute valuable substitutes for the mauve colour.

The method of fixing these colouring-matters to cotton, invented by Mr. Dale, jun., which promises to be valuable, may be mentioned here. The goods are prepared with a solution of colouring-matter and tannin, and are then passed through a bath containing tartar emetic. The affinity of the former substances for antimony determines the fixation of the colour on the fabric.

XXIV. Disinfectants.

The manufacture of disinfectants has now become a regular and constant one; and since the inquiries instituted on the subject by one of us and Mr. M'Dougall of this city, the use of those made in this district has been enormously increased. Mr. M'Dougall manufactures, near Oldham, a disinfecting-powder, in which the properties of carbolic and sulphurous acid are taken advantage of. This powder is used to prevent decomposition in stables, cowhouses, and among accumulations of putrescible matter, and generally for the prevention of decomposition in manures. A liquid is also prepared with carbolic acid and lime-water, which is applied for the purpose of preventing decomposition in sewers, thus carrying out the idea first started by one of us, of purifying whole cities by preventing the generation of gases in sewer water, or among accumulations of refuse. This liquid is also used to prevent the decomposition of animal matter when it cannot at once be made use of, especially in the case of meat brought to market, or animals that have died in the fields. The powder, which is called "M'Dougall's disinfecting-powder," is simply a mixture of the sulphites of lime and magnesia with the carbolates of the same bases. The carbolates of lime and magnesia are formed by simply boiling carbolic acid for a long time with the bases in a caustic state. The solution consists of carbolic acid dissolved in lime-water. It is extremely bulky; still $\frac{1}{1250}$th to $\frac{1}{1000}$th part of the bulk of the sewer water is sufficient to disinfect the latter. The solution of the powder has also been used to some extent in dissecting-rooms, where it immediately destroys any noxious smell, and at once liberates the fingers of the operator from the peculiarly nauseous odour which so often attaches to them. It has also been found useful in the treatment of sores, as well as of dysentery. M. Lemaire has lately read papers on tar oil and phenic acid; but Manchester claims priority in the application and explanation of these preparations.

Mr. M'Dougall has also applied carbolic acid to the destruction of parasitic insects on sheep, and has in many districts entirely driven out the arsenical preparations by the use of this acid united with fatty substances. Sheep dipped in it are not liable to be attacked by tick, even when left for some months among other sheep infested with it. Foot-rot and other diseases of sheep are also said to be prevented and cured by its use.

Mr. Pochin has introduced lately a very extensive manufacture which has greatly affected the mode of using alumina, and also the manufacture of alum. The substance is called *alum-cake*. It is sulphate of alumina with about 16 equivalents of water and silica. Very fine white clay is stirred round with sulphuric acid of about 140·0 sp. gravity, then warmed to about 100° F., and poured into a square trough with moveable sides. In a few minutes the action of the acid on the clay becomes very violent, and a sulphate of alumina is formed with the silica of the clay intimately mixed. If very strong sulphuric acid is used, the action becomes so violent that the whole mass is thrown out of the trough. The whole hardens into a compact mass difficult to break. To facilitate the fracture, wedges of iron were pressed into the mass when soft, the sides of the trough were taken down, and by striking the wedges the whole was broken into pieces. Now, however, a more elaborate machine is used to break it up into small portions.

In this manufactured article there is a large quantity of alumina, viz. 12·8 per cent. in a soluble form; the trouble of crystallizing is avoided, and the silica is in no way injurious in most cases. In some cases, where alum is used with resin for paper size, the addition of the silica is indeed considered an advantage. At any rate, the manufacture is constantly increasing; if silica be objected to, it is allowed to fall down, and a clear solution of sulphate of alumina remains.

On Ethno-Climatology; or, the Acclimatization of Man. By James Hunt, *Ph. D., F.S.A., F.R.S.L., Foreign Associate of the Anthropological Society of Paris, Honorary Secretary of the Ethnological Society of London.*

[A communication ordered to be printed among the Reports.]

One of the most important and practical duties of the ethnologist at the present day is the endeavour to discover the laws which regulate the health of man in his migrations over the world. The generally received opinions on this important subject are, however, vague and unsatisfactory.

From some cause, it is the popular belief that man stands entirely alone in the animal kingdom with regard to the influence exerted on him by external causes. We are told that man can thrive equally well in the burning heat of the tropics and in the icy regions at the poles.

I purpose, therefore, in this paper to examine how far the supposition of man's cosmopolitan power is warranted by an induction from the facts at present known to us. We can gain nothing in Climatology from "*à priori*" arguments, as it is entirely an experimental science; and hitherto we have not been able to foretell with any certainty the exact effect which any climate would exert on an individual or a race. No one who reflects on the important bearings which the question of man's cosmopolitanism introduces will be inclined to doubt the gravity of the question, and its claims to the serious attention, not only of ethnologists, but of all who are interested in the great problem of man's future destiny. This question then has equal claims on the attention of the philosopher and the statesman. Our data may be at present insufficient to found an exact science of Ethno-Climatology, but I trust to be able to show that there exist the outlines of a great science, which bids fair to prevent that waste of human life which has hitherto characterized the reckless policy of British colonization. Dr. Boudin, who is well known for his researches on this and kindred subjects, has recently called the attention of the Anthropological Society of Paris to the question, and laments the great inattention which public men have hitherto given to such an important and grave subject. He very justly observes, "The problem is certainly one of the most important in the science of ethnology; for it governs the great questions of colonization, of recruiting men destined for distant expeditions, and of fixing the duration of the sojourn of foreign troops at certain stations, so as to render them effective in war. This question touches public health and social economy." Nor will it be necessary for me further to ask attention, when it is considered how largely the British nation is practically interested in having a correct and physiological system of colonization. I therefore bring this subject under your consideration with a desire of calling public attention to the powers of acclimatization possessed by the races of man in general, and by Europeans in particular. It is asserted that to man belongs the exclusive privilege of being the denizen of every region; for that with plants and animals such is not the case. This explanation has as often been accepted as satisfactorily showing that man enjoys privileges over the animal and vegetable kingdoms. That races of men are found in every climate is perfectly true; but a slight examination into the differences and peculiarities of the races of men will show that this argument is not so forcible as at first sight it appears. Theorists have often indulged in boasting of the superiority of man over the animal kingdom in his migrations over the world; but these writers have forgotten that it is civilization which greatly aids man to adapt himself (for a time) to every climate. We have heard much, too, of the acclimatization of animals; but there has been great exaggeration as to what has been really effected.

No one will attempt to deny that, physically, mentally, and morally, there does exist a very considerable difference between the denizens of different parts of the earth; and it is not proposed to inquire whether the various agents which constitute climate, and their collateral effects, are sufficient to produce the changes in physique, mind, and morals which we find; but, simply taking the various types of man as they now occur on the earth, we have to determine whether we are justified in assuming that man is a cosmopolitan animal, and whether the power of acclimatization be possessed equally by all the races of man known to us.

The conditions which prevent or retard the acclimatization of man are physical, mental, and moral. It is, however, impossible to discuss the effect of climate only on man, because we find that food is inseparably connected with climate, and that both are modified by the physical conformation of the districts inhabited. The exercise or neglect of mental culture must also be considered. It is therefore nearly impossible to decide to which class we must ascribe certain effects; but there can be little doubt that all these causes act in harmony, and are insensibly bound together. In speaking, therefore, of climate, I use the word in its fullest sense, and include the whole cosmic phenomena. Thus, the physical qualities of a country have an important connexion with climate; and we must not simply consider the latitude and longitude of a given locality, but its elevation or depression, its soil, its atmospheric influences, and also the quantity of light, the nature of its water, the predominance of certain winds, the electrical state of the air, &c., atmospheric pressure, vegetation, and aliment, as all these are connected with the question of climate.

Now we find man scattered over the globe, and existing and flourishing under the most opposite circumstances. Indeed, there seems no part of the earth in which man could not, for a period at least, take up his dwelling. When Capt. Parry reached 84° of north latitude, it was the ice, and not the climate, which prevented him from reaching the pole. Man may live where the temperature exceeds the heat of his blood, and also where mercury would freeze; so man may exist where the atmospheric pressure is only one-half of what it is at the level of the sea. Men have been found permanently residing 12,000 feet above that level.

There is a difference between the climate of the N. and S. hemispheres under apparently the same circumstances. Thus, the European cannot live for any time at any great elevation in the northern hemisphere. The highest inhabited place of Europe has generally been considered to be the Casa Inglese, a small building of lava on Mount Etna, near the foot of the uppermost crater, 9200 feet above the level of the sea. There is, however, a house in the Theodal Pass, between Wallis and Piedmont, at an elevation of 10,000 feet*. These buildings are, however, only inhabited during the summer months. In the southern hemisphere there are permanent inhabitants in regions from ten thousand five hundred feet to twelve thousand feet above the level of the sea. Dr. Tschudi, who has himself resided in these regions, describes what is known as the "Puna sickness," which is what may be called a mountain-sickness, and very much resembles sea-sickness. The Peruvians live and thrive well at elevations of from seven to fifteen thousand feet above the level of the sea—heights said by some observers to be often destructive to the whites. This difference between the north and south hemispheres is caused, perhaps, by the difference in attraction at the north

* Perty, Vorschall der Naturwissenschaften, 1853.

pole. In the northern hemisphere the ascent of a high mountain causes a rush of blood to the head, and in the southern there is an attraction of blood to the feet; hence the cause of the sickness.

An examination of the human race shows us that every family presents different modifications, which are doubtless connected in some way with the nature of the cosmic influences by which they are surrounded. We know that some plants and animals are peculiar to certain regions, and that if transplanted to other climates they degenerate or die; such is the case with man. In every climate we find man organized in harmony with the climate; and if he is not in harmony, he will cease to exist. The general scale of power for enduring change is in certain respects in unison with the mental power of the race, and is also dependent on the purity of blood. Uncivilized and mixed races have the least power, and civilized pure races the greatest. Every race of man, however, has certain prescribed geographical salubrious limits from which it cannot with impunity be displaced. Such, at least, is the lesson I have drawn from existing data. It is civilization which chiefly enables the European to bear the extremes of climate. Indeed, a people must be civilized to some extent before they desire to visit distant regions. The Esquimaux, for instance, is perfectly happy in his own way, and has no desire to move to a warmer climate. His whole body and mind are suited for the locality; and were he moved to a warm climate, he would certainly perish. The whole organism of the Esquimaux is fitted solely for a cold climate; nor is such a supposition problematical and inexplicable by known physical laws. On the contrary, the physiological explanation of such a phenomenon is quite simple. Thus, the European going to the tropics becomes subject to dysentery; and the Negro coming to Europe, to pulmonary complaints. Europeans who have recently arrived at the tropics are instantly known by their walk and general activity. This, however, soon subsides, the organic functions become disturbed, the pulse and circulation are more active, the respiration less so, while the muscular fibre loses its energy; the stomach also becomes very weak. The action of the skin becomes abnormal, while the heat acts on and excites the liver.

It is often stated that tropical climates stimulate the organs of generation, but this is contrary to experience. That there is a low state of morality, and that the inhabitants of these regions are essentially sensual, cannot be denied; just as the cold region is distinguished by the gluttony of its inhabitants, and temperate regions by increased activity of brain.

The geography of disease has a most important bearing on this subject. It is somewhat strange that man suffers more from epidemics than animals, and this is probably owing to his neglect of the laws of diet, which require to be adapted to every climate. Thus we find that the temperate zone, which ought to be by far the healthiest, has more diseases than either the hot or the cold zones. The cold zone has but a small number of diseases; and in the torrid zone the number is not large, although the diseases are generally very malignant. Attempts have been made to classify diseases into three categories—those of hot, cold, and temperate regions. Such a classification is, however, arbitrary and most unsatisfactory; for the same climate may be found in each of the three regions. In the tropics there are temperate and cold regions, just as there is equatorial heat in the temperate zone. Dr. Fuchs* distinguishes these three regions of disease. The first he calls the Catarrhal region. This is so denominated because catarrh of the respiratory organs predominates in it. "Catarrh," he says, "is the com-

* Medicinische Geographie. By Dr. C. Fuchs, 1853.

mon cause of disease in the north temperate zone, between 1300 and 3000 feet above the level of the sea; in the central temperate zone, between two and seven thousand; within the tropics, between seven and fourteen thousand feet; in the cold zone, near the level of the sea." The other two regions he calls the Entero-mesenteric region, in which gastric complaints predominate, and the Dysenteric region, in which there is no scrofula or tubercular disease. Without entering into the value of this classification, medical statistics seem to prove that there are three zones:—1st, the cold or catarrhal zone; 2nd, the tropical or dysenteric zone; and 3rd, the temperate or gastric and scrofulous zone. This last zone, however, seems to be subject to the diseases of the other two zones, which prevail respectively according to the seasons. The scrofulous zone ceases at an altitude of two thousand feet above the level of the sea; here there is no pulmonary consumption, scrofula, cancer, or typhus fever.

It has been suggested that the perfection of the races in the temperate zone depends on the conflict to which they are subjected by the irruption of diseases from the other zones,—the unfavourable climatic conditions producing a human organism capable of resisting them. Dr. Russdorf* says, "The climatic conditions of the temperate zone act in the formation of blood in such a manner that a large quantity of albumen is present in it. This richness in albumen is manifestly requisite to produce and nourish the powerful brain which distinguishes the Caucasian race; for the brain mainly consists of albumen combined with phosphorated fatty matter." "It is the brain of the Caucasian which determines his superiority over the other races; it is the standard of the power of the organism; it might be termed the architect of the body, as its influence upon the formation of matter is paramount. The effect of the atmosphere upon the formative activity of the organism and upon the metamorphosis of matter is so great, that it is, for instance, on the influence of the oxygen absorbed by the skin and the lungs that the metamorphosis of the albumen into muscle, &c., directly depends. The atmosphere of the temperate zone favours such a change of matter that the blood remains rich in albumen, so that a large brain can be nourished. But this richness in albumen is also the cause of many characteristic diseases, when this substance, under the process of inflammation, is morbidly excited in the tissue of the organs and destroys their anatomical structure or organic mechanism. That general condition, in which the consumption of the albumen by the organic metamorphosis is deficient, is well known as the scrofulous predisposition of the European, which is unknown among the inhabitants of the tropics and the cold zone."

Two questions then await a solution: 1st, Can any race of men flourish, unchanged both mentally and physically, in a different ethnic centre from that to which it belongs?

2nd, Can any race of men move from its own ethnic centre into another, and become changed into the type of that race which inhabits the region to which it migrates?

Now, races of men moving from one region to another must either degenerate and become extinct, or flourish with the same distinctive characters that they have in their own regions, or they must gradually become changed into new types of men suited to their new positions.

That new races of men are being formed at this time is highly probable, as where, for instance, we have in a particular region a class of men with the same temperament and character. This may, as in the case of America,

* Vorträge zur Förderung der Gesundheitslehre (The Influence of European Climate). By Dr. C. von Russdorf, 1854. Berlin.

give rise to a new race, but still belonging to the European type, just as we have in this country the distinctive class of the Quakers, &c. But this change in the so-called Anglo-Saxon race could have been effected without removing them out of their own region. If these men had congregated together in Europe, we should have had a group of men with different feelings and opinions from our own. The congregation of a number of men and women of similar character would always tend to increase or intensify the special characteristics of the descendants of such people. Some writers, in their anxiety to prove that climate has nothing to do with the varieties of man, deny that there is any change in the European inhabitants of America; but recent events have given strong proof that there is a change, both in mind, morals, and physique; and while this change is not to be entirely ascribed to the climate, there still is good presumptive evidence that the Europeans have changed in America, especially in North America. In the children of the colonists there is a general languor, great excitability, and a want of cool energy. As they grow up, they neglect all manly sports. This general excitability and want of coolness and energy are also seen in the whole Yankee race. The women become decrepit very early, and consequently cease to breed while still young. It is also affirmed that the second and third generations of European colonists have small families. Some fifteen years ago, Dr. Knox stated publicly that he believed the Anglo-Saxons would die out in America if the supply of new blood from Europe was cut off. Such an assertion was, indeed, startling for any man to make; it seemed to bear on the face of it a palpable absurdity. But, as time has passed on, this statement certainly became less baseless, and is now, at least, an hypothesis as worthy of our attention as any other explanation of this difficult question. Emerson has recently remarked on this extraordinary statement of Dr. Knox, that there is more probability of its truth than is generally thought. Emerson* says, "Look at the unpalatable conclusions of Knox—a rash and unsatisfactory writer, but charged with pungent and unforgetable truths." He continues, "The German and Irish millions, like the Negro, have a deal of guano in their destiny. They are ferried over the Atlantic, and carted over America to ditch and to drudge, to make corn cheap, and then to lie down prematurely to make a spot of green grass on the prairie."

I do not purpose to give any categorical answers to the queries suggested, but simply to bring forward some facts, and to give the opinions of some men who have paid attention to this and allied questions. Thus I trust to lay a basis for further investigation, and induce more labourers to enter the field for the purpose of developing this important question.

We must not take latitude simply as any test of climate; for the general climatological influences are very different in various regions. Thus, it has been noticed that the west coast is colder than the east in the southern hemisphere, while in the northern the east is colder than the west†. In the French Antilles, the temperature is between 62° F. to 77° F. on the shore, and descends to 55° F. or 60° F. at eight hundred metres above the level of the sea. At Fernando Po, the greatest heat known was from 83° to 100° F.; generally it is about 73° F. So French Guiana is said not to have a higher temperature than Algeria. Some parts of Australia and New Zealand are nearer the equator than Algiers, and yet the temperature and salubrity are very different. The effect of light is also most important, and

* The Conduct of Life. By R. W. Emerson, p. 10.

† See what Darwin says respecting the fig and grape ripening in South America much better on the east than on the west coast.

is not merely confined to the skin, but affects the whole organism. The presence of light modifies the qualities of the air; it also acts on the nervous system. If we look at the analogy of the effect of the absence of light on organized beings generally, we shall readily understand the influence which it exerts on man. Europeans, indeed, who live in darkness have colourless skin, the muscles soft, and the whole body bloated. It is, therefore, a question which has yet to be decided, how far the Esquimaux's ill-formed frame may be produced by the want of light. And here we find that insensibly our attention is called to the vexed question of the unity or the plurality of origin of mankind. With that subject, however, we have at present nothing to do. It is, however, on the assumption of unity of origin that the cosmopolitan powers of man have been imagined to exist. I hold the questions of unity or plurality, however, to be of little or no consequence in the present state of our knowledge.

When we see that plants and animals vary in different climates, we are led to expect that man will also vary with the climate. Plants growing like trees in the tropics, become dwarfed in cold climates. It would, indeed, be strange that, as all animals vary, man should remain unchanged. But while admitting that man exists in harmony with external circumstances, we do not admit that one type of man can be changed into another. As the rose will under no change of external circumstances become a blackberry, so neither will a dog become a wolf, nor a European an African Negro. We shall, therefore, principally confine our attention to the inquiry whether man migrating from one region to another gradually degenerates. If there is degeneration going on, it is simply a question of time, as to how soon his race will become extinct. I shall, therefore, contend that any race migrating from one centre to another does degenerate both mentally and physically. Indeed, the psychical change produced in man by climatological influence is as soon visible as the change produced on his physical frame. When, for instance, the European goes to Africa, he, for a short time, retains his vigour of mind; but soon he finds his energies exhausted, and becomes listless, and nearly as indifferent to surrounding events as the natives. There is, however, a considerable difference in the effects produced both on individuals of the same race, as also on the different races of men. Some are affected immediately on their arrival, and then appear to become partially acclimatized; often the disease increases until it becomes very serious; again, others are attacked, without any warning, with either inflammation of the brain or liver. Others, again, do not appear at first to be at all affected; but gradually the strength gives way, the countenance becomes despondent, and chronic disease of the liver or stomach results.

Neither can the inhabitants of tropical regions generally withstand the influence of removal to a cold climate. Much, however, depends on race; for the different races of man have different degrees of adaptability for change of climate. We cannot, however, yet decide the exact powers of each race, as ethno-climatology is a new study, and a long series of observations is required before a satisfactory answer can be given.

Before I proceed to indicate the sort of evidence we can get from that most valuable of all modern sciences, statistical science, I think it will be well that I should quote some few authorities to show that there is an agreement between the most recent writers on this subject and the lesson we learn from statistics. Dr. A. S. Thomson, who has paid great attention to this subject, observes, "There is little doubt that the tropical parts of the world are not suited by nature for the settlement of natives of a temperate zone. European life is but with difficulty prolonged, much sickness is suffered, and their offspring become degenerate and cease to propagate their species in a few generations; and should necessity force Europeans to perform the drudgery of labouring in the field, their lives will be rendered still shorter, and their existence little better than a prolonged sickness." Dr. Thomson has entered into the various attempts of the Portuguese, Dutch, English, French, and Danes to colonize India. He has also dwelt on the attempts of the Dutch and Spaniards at colonization in the Indian Archipelago, and also on the state of European colonies in tropical Africa and tropical America. His conclusion is, "that man can only flourish in climates analogous to that under which his race exists, and that any great change is injurious to his increase and also to his mental and physical development."

Sir Alexander Tulloch well observes, that military returns, properly organized and digested, serve as the most useful guides "to point out the limits intended by nature for particular races, and in which alone they can thrive and increase"—boundaries which neither the pursuit of wealth nor the dreams of ambition should induce them to pass, and proclaim, in forcible language, that man, like the elements, is controlled by a Power which hath said, "Hither shalt thou come, but no further."

Let us glance at the attempts of the French to colonize the North of Africa.

The mortality of the civil population in France is about twenty-five in a thousand, while the average mortality of the civil population in Algiers, in 1853, was 43·5, and in 1854, 53·2 in a thousand. "In all the localities of Algiers, without exception," says M. Boudin, "the mortality of the European population exceeds by far, not merely the normal mortality of England and France, but even that of the cholera years in these two countries." Notwithstanding these facts, the population is annually increasing by the influx of immigrants. As regards other colonies, the following table, quoted by M. Boudin from the official report of the Ministry of Algeria, published in 1859, speaks for itself:—

	Births.	Deaths.
Guadaloupe	20,095	20,675
Guiana	2,333	2,830
Réunion	18,934	20,775

This would be more satisfactory had the proportion of the women to men been also given.

But, before I proceed on this side of the question, I would call attention to the statement frequently made by the President of this Section. On one occasion, for instance, Mr. Crawfurd* said, "It has been confidently asserted that the British possessions in India are an unfit residence for the permanent dwelling of Englishmen, although within the same latitudes with the warm parts of America, and portions of it even more distant from the equator." "No less an authority," continues Mr. Crawfurd, "than the late Duke of Wellington gave it as his opinion that Europeans, especially in Lower Bengal, most of which is without the tropics, would die out in a third generation; but it is certain that this was an hypothesis of His Grace unsupported by facts." Mr. Crawfurd further contends that the Duke of Wellington's observation was made at an unfavourable time, and that at present the case is very different. Now all recent facts and observations prove that the Duke of Wellington was right. From numerous private inquiries of residents in India I have obtained confirmation of this opinion. We have, moreover, the most extensive writers and observers on tropical diseases giving exactly similar opinions.

* "On the Effects of Commixture, Locality, Climate," &c., Transactions of the Ethnological Society, New Series, vol. i. p. 89, 1861.

Sir Ranald Martin* says, "Of those Europeans who arrive on the banks of the Ganges, many fall early victims to the climate, as will be shown hereafter. That others droop, and are forced, ere many years, to seek their native air, is also well known. That the successors of all would gradually and assuredly degenerate if they remained in the country cannot be questioned; for already we know *that the third generation of unmixed Europeans is nowhere to be found in Bengal.*"

William Twining also made the same assertion many years ago.

Another recent authority on India†, Mr. Julius Jeffreys, says, "Few children of pure English blood can be reared in the plains of India, and of that few the majority have constitutions which might cause them to envy the lot of those who die in their childhood. The mortality of barrack children is appalling, especially in the months of June, September, and October. At Cawnpore from twenty to thirty have died in one month. *In short, the soldiery leave no descendants of unmixed blood.*" Major-General Bagnold ‡ has also said, that the oldest English regiment, the Bombay "Toughs," notwithstanding that marriages with British females are encouraged, have never been able, from the time of Charles II. to this time, to raise boys enough to supply the drummers and fifers. Dr. Ewart § says, "Our race in process of time undergoes deterioration, physically and intellectually, with each succeeding generation, and ultimately ceases to multiply and replenish the earth." He also says, "that there is a certain deterioration of our race always, under present circumstances, tending to extinction in this country."

It remains, therefore, with Mr. Crawfurd and those who agree with him to accept these facts, or explain what has become of the descendants of the half million of people who have gone to India. It is generally supposed that there is a process of acclimatization going on with Europeans living in the tropics; but the reverse is rather the case. It is true that the mortality is sometimes greater at first, but this is owing to the clearing out of the weakened and other defective constitutions which had been broken down by disease or intemperance. When this has taken place, there appears to be an improvement; but after the first year there is a gradual decline in health, and sickness and mortality greatly increase. *We have exhaustion and degeneracy, but no real acclimatization.* Although Europeans suffer less on going to colder regions, still we observe the same fact in that case. Dr. Armstrong and others have observed that Europeans resist the cold of the polar regions better the first year than they do the second, and that every subsequent year they feel the effects of climate more.

This fact can be amply proved by statistics. As age increases, so does mortality in any place out of the native land of a people.

Dr. Farr gives the average per thousand of England and Wales as—

Ages	20—24.	25—9.	30—34.	35—39.	40 and upwards.
Mortality	8·42	9·21	10·23	11·63	13·55

Now, if we compare this with a part of a valuable table prepared by Sir Alexander Tulloch ‖, we at once can estimate some of the deleterious effects of change to different climates on Europeans, from January 1, 1830, to March 31, 1837.

* Influence of Tropical Climates, &c., 2nd edit., by Sir R. J. Martin, p. 137, 1861.
† The British Army in India. By Julius Jeffreys, F.R.S. 1858, p. 172.
‡ Indigenous Races of the Earth. Article "Acclimatization," by Dr. Nott, p. 557.
§ Digest of the Vital Statistics of Europeans in India. By Joseph Ewart, M.D. 1859.
‖ Report of the Commissioners on the Reorganization of the Indian Army. 1859, p. 179.

Stations.		18 to 25.	25 to 33.	33 to 40.	40 to 50.
Gibraltar	Mediterranean	18·7	23·6	29·5	34·4
Malta	Mediterranean	13	23·3	34	56·7
Ionian Islands	Mediterranean	12·2	20·1	24·4	24·2
Mediterranean Stations generally		15·5	22·2	28·1	33·
Bermudas	North America	16	42	42	76·
Nova Scotia	North America	14	22·5	30·8	41·5
Canada	North America	19·7	27·8	37·8	35
Windward and Leeward command		50	74	97	123
Jamaica		70	107	131	128
Cape of Good Hope		9	20·6	29·7	32
Mauritius		20·8	37·5	52·7	86·6
Ceylon		24	55	86·4	126·6
Bombay		18·2	34·6	46·8	71·1
Madras		26	59·3	70·7	86·5
Bengal		23·8	50·3	50·6	83·3

A modification of the same results is found from 1837 to 1847.

	Age. 20—25.	Age. 25—30.	Age. 30—35.	Age. 35—40.	Age. 40 and upwards.
Mediterranean stations	16·3	15·1	16·4	23·4	34·4
Canada Nova Scotia	13·1	17·7	19·2	20·3	35·6
Jamaica	60·	50·	73·	83·	97·

The following very useful table I have collated from the valuable Army Report for 1859. It would be very desirable if some tables were given to show the different periods that men had been located at each station.

Although this table is valuable, it must be borne in mind that it is only for one year. Troops are so continually changing stations that we must only receive the suggestive evidence of such a table for what it is worth. It will be seen that there are no deaths in some stations at forty years of age and upwards; this is, however, simply because it frequently happens that there are no men in a regiment above that age.

Annual ratio of deaths per thousand living, at the following ages, in 1859:

	Under 20.	20—24.	25—29.	30—34.	35—39.	40 and upwards.
Healthy districts in England and Wales	5·83	7·30	7·93	8·36	9·	9·86
England and Wales generally	7·41	8·42	9·21	10·23	11·63	13·55
Household Cavalry	...	3·38	6·85	9·05	16·13	15·04
Dragoon Guards and Dragoons	5·07	4·0	12·96	15·0	15·86	34·48
Foot Guards	7·92	7·34	7·80	12·07	26·47	9·71
Infantry Regiments	5·82	7·21	7·80	11·97	18·31	15·50
Depôt Battalions	6·31	20·13	12·39	20·11	37·97	44·78
Bermuda	...	10·0	5·35	24·15	48·08	...
Nova Scotia, &c.	10·20	5·06	2·51	36·15	...	...
Newfoundland	...	...	...	...	13·51	...
Canada	8·85	8·94	11·54	4·42	15·27	10·38
Mediterranean generally	9·28	12 01	20·78	25·64	12·15	55·55
Cape of Good Hope	...	7·93	14·69	9·31	14·78	·60
Australian Colonies	...	1·94	6·91	7·06	26·59	23·81
Negro in W. Indies, W. and L. command	9·71	11·24	32·41	39·02	6·25	...
Ceylon Rifles	10·99	8·23	8·72	9·68	11·05	14·49

With officers and the civil servants in Bengal, we also find that the mortality greatly increases with length of residence, notwithstanding the great advantage which they have of being able to return to their native country. "Out of 1184 deaths among officers," says Sir Ranald Martin*, "the proportion occurring annually in each rank, and at each age, has been as follows:—

Percentage of deaths.	Colonels, average age 61.	Lieut.-Colonels, average age 51.	Majors, average age 40.	Captains, average age 36.	Lieutenants, average age 18 to 33.	Cornets and Ensigns, average age 18 to 33.	General average at all ages.
Died annually per thousand of each class.	59·4	48·4	41·0	34·5	27·5	23·4	31·2

"The mortality among the civil servants, for a period of forty-six years, from 1790 to 1836, exhibits almost precisely the same results, viz.:—

Percentage of deaths.	Above 50 years of age, and 30 of service.	Age 40 to 50, service 25 to 30.	Age 40 to 45, service 20 to 25.	Age 35 to 40, service 15 to 20.	Age 30 to 35, service 10 to 15.	Age 25 to 30, service 5 to 10.	Age 20 to 25, service 1 to 5
Died annually per thousand of each class.	48·6	36·4	35·4	23·4	16·6	20·8	19·9

"Between ten and fifteen years' service is the period when leave of absence is allowed to those who choose to return to Europe for three years, which of course must have a material tendency in reducing the mortality of that class."

The high mortality of our own army at home may also be greatly ascribed to the weakening influence of the climates of many of our foreign stations. The annual mortality per thousand was—

	Age. 20—24.	Age. 25—29.	Age. 30—34.	Age. 35—39.	Age. 40 and upwards.
Infantry. From 1837 to 1846	17·8	19·8	12·8	21·	23·4
In 1859	7·21	7·80	11·97	18·31	15·50
Depôt battalions, in 1857	10·13	12·39	20·11	37·97	44·78
England and Wales generally	8·42	9·21	10·23	11·63	13·55

In the useful Army Statistical Report, from which these facts are taken, this high mortality of the depôt battalions is acknowledged to be "attributable to the number of men serving in them whose constitutions have been impaired by foreign service, and many of whom have been sent home to the depôt labouring under chronic disease contracted abroad†."

We can best estimate the deleterious influence of climate by comparing the relative mortality of native and foreign troops. Everywhere we see the same law. At Gibraltar, the deaths per thousand of the Malta Fencibles

* Loc. cit. p. 96.

† Statistical, Sanitary, and Medical Report for 1859, p. 28.

(although nearly all old men) was, in 1859, 8·19, while with the British troops it was 18·08 per thousand. On the West Coast of Africa, there are no white troops to compare with the black troops. The Army Report says, "The force consisted entirely of blacks, with the exception of four or five European sergeant-majors, of whom three died in the course of the year—two of fever at the Gambia, and a third of dysentery at Accra."

The deaths of black troops at Sierra Leone, in a thousand, was 14·02; at the Gambia, 25·44; and on the Gold Coast, 25·06. The mortality of the white troops serving at Ceylon, from 1837 to 1846, was 41·74 per thousand; and in 1859 the mortality decreased to 35·06: while, with the so-called black troops, the deaths in a thousand, from 1837 to 1846, were 26·71; and in 1859, 10·19. The ratio of mortality with the Ceylon Rifles (Malays) is the same as that of the male population of this country. In the same Report we find, under the head of China, what are called "native troops," which we discover to be Bengal Native Infantry, &c. The mortality of these troops from India is at the rate of 53·73 per thousand, without reckoning those who died subsequently from disease contracted in China; while, with the British troops serving in China, the mortality slightly exceeded that of the Indian troops, being 59·35 per thousand—no less than 42·58 of this number having died of miasmatic disease. Sir T. G. Logan, in his Report on the Sanitary State of the Army, says, "The topographical character, however, of Hong Kong was acknowledged to preclude improvement to any considerable extent in the health of European troops, and its retention as the chief military station of the command could not be thought desirable in a sanitary point of view. The principal medical officer's report refers to the circumstance that the annual expenditure of men by death and invaliding had been averaged at 20 per cent., being more than double of what it is in India; and that, notwithstanding every means had been taken, and no expense spared, to preserve the health of the troops, the results were still very unsatisfactory."

But the great mistake which most writers on the diseases of tropical countries commit is the neglect to ascribe the large amount of disease to the true source, viz. the inadaptibility of Europeans to tropical countries. Nearly every medical writer on the diseases of India tries to prove that the large mortality is produced by some preventable cause; but a little inquiry into the diseases which attack the natives and Europeans will destroy this delusive hope. First, then, with a given strength of Europeans and natives we find that, with the three sorts of FEVERS, intermittent, remittent, and continued, there are in

Bengal	3·76	deaths of Europeans to 1 Native.
Bombay	2·54	„ „ to 1 „
Madras	1·23	„ „ to 1 „

The admissions for fever amongst Europeans were from

		Percentage of admissions to strength.	Deaths.
Bengal	1812 to 1815	84·85	6·50
	1850 to 1854	100·25	100·06
Bombay	1811 to 1814	66·34	2·21
	1850 to 1854	63·10	0·78
Madras	1829 to 1832	29·52	1·21
	1848 to 1851	28·46	0·52

While with the native troops the following is the result:—

		Percentage of admissions to strength.	Percentage of deaths to admissions.
Bengal from	1826 to 1838	41·30	1·32
	1839 to 1852	53·16	0·96
Bombay „	1803 to 1828	53·18	1·80
	1828 to 1853	46·55	1·18
Madras „	1827 to 1835	21·27	1·46
	1842 to 1852	28·5	1·01

The large amount of deaths among the native soldiers may be greatly ascribed to the inadaptibility of our English pharmacopœia. Since our contact with the natives they are every year becoming more liable to all sorts of diseases, but especially fevers and bowel diseases. The high mortality amongst the natives must, therefore, be greatly ascribed to our inability to check disease in them. The deaths to the number of admissions are even greater amongst the natives than amongst Europeans. This, in itself, is a pretty good evidence for the assertion that a healing art has yet to be discovered for their constitutions.

Then with DYSENTERY and DIARRHŒA, the proportion of deaths of Europeans to natives is in

Bengal	11·67 of Europeans	to 1	Native.
Bombay	8·73 „	to 1	„
Madras	6·53 „	to 1	„

The contrast is sufficiently great with fevers and dysentery; but it is still more marked with hepatitis:—

In Bengal,	60 Europeans	die of HEPATITIS to	1	Native.
Bombay,	44 „	„	1	„
Madras,	30 „	„	1	„

Even in those hot-beds of disease, the Indian jails, we find the inmates are far more free from hepatitis than our own troops in Bombay: the Europeans are attacked thirteen times oftener than the natives; in Bengal, forty-three times; and in Madras, our soldiers one hundred and seventy-eight times oftener.

Some writers have endeavoured to show that this disease is produced in Europeans by intemperance. But Dr. Morehead* says, "The evidence that intemperance in drinking exerts a particular influence in the production of hepatitis is by no means conclusive;" and he also says, "The occurrence of hepatitis, on the other hand, in its severest form is not an unusual event in persons of temperate habits,—a statement which practitioners in India generally will, I am sure, amply confirm."

With CHOLERA, the ratio of mortality is in

Bengal	6· Europeans	to 1	Native.
Bombay	2·6 „	1	„
Madras	1·18 „	1	„

There is also another fact which demands attention, viz. the increase of mortality in cases attacked with this disease. Whatever may be the cause, there seems to have been far higher mortality in Bengal since 1838, and in Madras since 1842, than before those periods. Thus, the relative mortality to the cases treated in Bengal has risen in each period of five years, from 1818 to 1853, from 26·71, 31·17, 21·80, 26·91, 55·53, 45·22, and 41·92 per cent.; and in Bombay, during the same time, from 18·53, 22·71, 30·58,

* Diseases of India. By Charles Morehead. 2nd edit. 1861, p. 363. Longman and Co.

18·87, 37·33, 45·46, and 43·17; and in Madras, from 1829 to 1851, from 27·11, 27·63, 48, and 62·31.

There has been an increase of mortality of natives to cases treated, in Madras, of 7·26 per cent.; in Bengal the mortality is about the same; and a decrease of 3 per cent. in Madras.

With phthisis (CONSUMPTION) the percentage of mortality to a given strength is—

In Bengal ....11 deaths of Europeans to 1 Native.
Bombay .... 4 " " 1 "

Thus, the deaths of Europeans from phthisis even exceed the native prisoners in our Indian jails.

In the various OTHER DISEASES which have not been mentioned, the mortality is far higher, being, in Bengal, as 3 Europeans to 1 native, and in Bombay as 3·2 Europeans to 1 native.

Many writers have observed that, with the natives, those most free from disease are those who toil all day in the burning sun, with no covering at all on the head. Ignorance as to the difference of race has induced some commanders to attempt thus to *harden* the Europeans, with results something frightful to contemplate.

One of the regiments that had been the longest in India, the Madras Fusileers, is stated to have been reduced from eight hundred and fifty to one hundred and ninety fit for duty. Many similar cases have been produced by needless exposure. Mr. Jeffreys says, "that Her Majesty's 44th Regiment in 1823 were nine hundred strong, and a very fine body of men. The commanding officer insisted that confinement of the men during the day was effeminate, and continued drilling them after the hot season had begun. But the men suffered the penalty of the officer's ignorance. For some months," says Mr. Jeffreys, "not less than one-third, and for some weeks one-half, of the men were in hospital at once, chiefly with fever, dysentery, and cholera. I remember to have seen, for some time, from five to ten bodies in the dead-room of a morning, many of them specimens of athletes." Experience has shown that it is not the absolute exposure to the sun from which Europeans suffer; it is the subsequent effects which are to be dreaded. On a march, the European will appear to be equal to the thick-skinned native; but he soon learns that such is not the case.

The European soldier is also unfitted to stand the effects of a cold climate after some years' residence in India, and dreads to return home to encounter the cold and hardships of English peasant-life. With officers, who can return to enjoy all the comforts and luxuries of civilization, the case is different. The few soldiers who remain in India have more or less chronic diseases, which, says Mr. Jeffreys, "would render the attainment of anything like longevity out of the question."

Seventy-seven per cent. of the European troops in Bengal are under thirty, twenty-three per cent. above that age; or ninety-four per cent. are under thirty-five, the remaining six above that age.

From Dr. Ewart* we learn that the European army has hitherto disappeared in Bengal in about ten and a half years; in Bombay, in thirteen and a half; in Madras, in seventeen and a half; or in all India, in about thirteen and a half years. We find the percentage of deaths to strength amongst European regiments, in Bengal, 6·94; in Bombay, 5·52; in Madras, 3·88.

Thus we find that, on adding all these diseases of European troops together, we get a mortality of at least seven per cent. for the whole of India, while

* A Digest of the Vital Statistics of the European and Native Armies in India. By Joseph Ewart, M.D., Bengal Med. Staff.

with the native troops the mortality does not amount to a half per cent. Sir A. Tulloch says, that "the total loss from all causes has been at least seventy per thousand;" and that "the proportion invalided annually may be taken at about twenty-five per thousand more, and twenty-five per thousand to men not renewing their engagements;" making altogether twelve per cent., or one hundred and twenty per thousand. He further observes, that the number of recruits raised during peace, from 1845 to 1849 inclusive, was less than twelve thousand; and that, with a force of eighty thousand in India, we shall require nine thousand and six hundred of them for India, "unless," as he observes, "means can be adopted to reduce mortality and invaliding."

Mr. Jeffreys says, the mortality of troops in India amounts to ten per cent. He observes, "The casualties amongst the troops have, *during peace*, amounted per annum to at least one thousand in every ten thousand; in England and her healthy colonies they have ranged from about ninety to a little above two hundred." Such being the undisputed fact, there is no doubt, as Sir A. Tulloch has observed, that "the selection of healthier stations for our troops than those they have hitherto occupied is no longer a matter of choice, but one of necessity, as we cannot hope to keep up the large European army required to hold India without the strictest attention to this important measure." The late Sir H. Lawrence devoted much of his life to the solution of this question in a practical manner. There is no doubt that removing our military stations to the hills is a measure demanding serious attention. Sir Ranald Martin is of opinion that, in Bengal and the N.W. Provinces, the malaria might be escaped by an elevation of from two thousand five hundred to four thousand feet. That this would be advantageous is quite probable; but we shall not find in the hills the same climate we have in this country. We may escape the influence of malaria-diseases, just as we escape the yellow fever in the West Indies, at an elevation of from two to three thousand feet. The Report for the Re-organization of the Indian Army gives the mortality from 1815 to 1855, exclusive of casualties, at a hundred thousand men, "the greater portion of whose lives," the Report says, "might have been preserved had better localities been selected for the military occupation of that country." But are there any places even in the hills in which Europeans can be reared without gradually becoming degenerated? This is a serious question, to which science can as yet give no positive reply. Looking at the wisdom which is displayed in the general distribution of mankind, we shall be inclined to answer in the negative. It has been presumed that, because yellow fever is in a great measure escaped in Jamaica at an elevation of about two thousand five hundred feet, this elevation would be sufficient to escape malarious diseases in other parts of the world; but such is not the case. If we ascend to any great height, we often get out of the region of malaria, and into the region of bowel-diseases. It is also affirmed* that "intermittent fever originates in some of the Himalayah stations. At Aboo also, during the malarious months, ague is very prevalent. Dr. Cooke (Bombay service), in his annual report of the Khelat agency, states that 'Khelat, the highest inhabited spot of the Beloochistan table-land, standing seven thousand feet above the level of the sea, is also malarious.'"

It has also been said by Sir John Lawrence, Brigadier-General Chamberlain, and Lieutenant-Colonel Edwards, that, besides our soldiers not liking to live in the hills, the natives have not the power of believing in what they

* Diseases of India. By Dr. Moore, Bombay Medical Service, and in charge of the Sanitarium for European troops at Mount Aboo. 1861, p. 48.

cannot see; and they join in asserting that "there are sick men whom the hills make worse, and healthy men whom they make sick*." General Sir A. Tulloch also allows† that the stations at 8000 or 9000 feet of elevation "are less healthy than was expected, because the men suffer from what is called a hill diarrhœa, which reduces them very much indeed." Many other authorities and facts tend to show that it is a great fallacy to assume that temperature and climate are at all the same thing. There may be the same ethnic climate, with vast difference of temperature. China, for instance, has very different temperatures; but this has hardly a perceptible effect on the race.

Dr. Ewart, like many other writers on this subject, has a theory which he believes would enable Europeans to be reared in India. He says, "The average standard of health of our race in this country would bear comparison with that of any race on the face of the civilized world, or of any people in Europe, provided the sources of malaria were dried up."

Although this is wholly a gratuitous assumption, we still have evidence to show that a very slight change is sufficient to make a considerable change in the health of soldiers. Mr. M'Clelland‡ says, "that out of a European force of little more than one thousand, there were four or six funerals daily; and this great mortality was checked by a change to the hills, which were only one hundred or one hundred and fifty feet high. It is probably a mistake, however, to attribute this favourable change in the mortality to the climate; it was doubtless far more due to the influence on the brain and nervous system. If the cause which produces *ennui* amongst all classes of European residents in India could be eradicated, then perhaps the case might be different. A number of plans have been proposed to enable the European to live in India. In 1853-4, the expenditure for cinchona bark and quinine amounted to £11,686. It is now proposed to give quinine as a prophylactic for fevers, and there will be a demand for £46,744 worth§. But the process that is now seriously proposed by Desmartis ||, in harmony with his theory of inoculation, is to transfuse a small quantity of blood taken from the natives into the veins of Europeans visiting such places as India, Brazil, or the West Coast of Africa! I would only beg to express a hope that in transfusing this blood they will not also transfer any of the mental or moral characteristics of these indigenous races into the European. If any process, however, can be devised to make Europeans like the natives, then we must remember that, instead of being able to hold down one hundred and fifty millions of people with about one hundred thousand men, we should want a very different number. It is only possible to hold India as long as Europeans remain the superior race. It has been asserted that, although they cannot bear the sudden change to a tropical climate, they can gradually become accustomed to the change. It seems a fair test of the influence of climate on race, to study its effects on the children of those who have become accustomed to the change, or, as it is sometimes falsely called, "acclimatized." Here there can be no question as to the effects of climate. We have seen what is the result of attempting to raise European children in India, and nearly the same result meets us elsewhere. Speaking of the effect of climatic influence on such children in Ceylon, Sir Emerson Tennent¶ observes, "If suitably clothed, and not injudiciously fed, children may remain in the

* Papers connected with the Reorganization of the Indian Army. 1859, p. 6.
† Minutes of Evidence on the Reorganization of the Indian Army, p. 266.
‡ Medical Topography of Bengal, &c. 1859, p. 135.
§ Ewart, p. 47.
|| Quelques mots sur les Prophylaxies. Par S. P. Desmartis. Paris, 1859.
¶ Ceylon. By Sir James Emerson Tennent. 1860, p. 79.

island till eight or ten years of age, when anxiety begins to be excited by the attenuation of the frame and the apparent absence of strength in proportion to development. These symptoms, the result of relaxed tone and defective nutrition, are to be remedied by change of climate, either to the more lofty ranges of the mountains or more providently to Europe."

Many writers, who contend that Europeans can become completely acclimatized, contradict themselves in their statements respecting the rearing of children. Mr. Robert Clarke, who has some eighteen years' experience on the Gold Coast and at Sierra Leone, goes so far as to say*, "It is questionable whether persons of colour are better able to bear up against the influence of climate than persons of pure European blood, provided the latter are sober in their habits. There can be no doubt that Europeans, on their first arrival in West Africa, are in greater danger of losing their lives than the former; but when once they have become acclimatized, they seem generally to withstand the influence of the climate better than coloured people, provided, I repeat, they are temperate in their habits." If this be so, we should not expect to find great mortality amongst children born of "temperate, acclimated Europeans." But Mr. Clarke says†, "Great difficulty is experienced in rearing European children. They in general thrive admirably until teething begins. It is at this epoch they are frequently harassed with intermittent fever, which by repeated occurrence causes enlargement of the spleen and functional disturbance of the stomach and bowels, when they soon became cachectic, and unless removed to a more genial climate drop into an early grave."

Some authors think that the question of the European propagating himself in the tropics has been settled by the fact that for three centuries the Spanish race has lived and thrived in tropical America. Mr. Crawfurd says, "The question whether the European race is capable of living and multiplying in a tropical or other hot region seems to have been settled in the affirmative on a large scale in America. Of the pure Spanish race there are at present probably not fewer than six millions, mostly within the tropics." But it is a wholly gratuitous assumption, unsupported by facts, to suppose that anything like this number of the Spanish race exist in America. If we were to read for Mr. Crawfurd's "millions" the word "thousands," we should perhaps be nearer the truth. In Mexico it is estimated that there are not more than ten thousand of the pure race‡, reckoning both creoles and immigrants. What a small proportion is this to those who left their native land and have never returned again! For three hundred years Spain has poured out her richest blood on her American colonies, almost at the price of her own extinction, without the slightest prospect of being able to establish a Spanish race in Central America. Never was there a greater failure than the attempt of the Spaniards to colonize tropical America. Those who have watched the gradual change of the Spanish colonies must be convinced of the fallacy of quoting this as a case of successful colonization of tropical countries by Europeans. When the continual influx of new blood from Spain was taking place, the change was not so much observed; but, now emigration has ceased, the pure Spanish race is diminishing rapidly. All recent observations show that the Indian blood is again showing out in a most remarkable manner. Instead of the Spaniards flourishing, there seems every prospect of their entire

* Reports of H. M. Colonial Possessions for 1858, Part ii. p. 33.

† Topography and Diseases of the Gold Coast, 1861, p. 48.

‡ It has since been asserted in the Cortes, by Don Pachero, that the pure Spanish race in Mexico does not amount to more than eight thousand. In 1793, Humboldt estimated the pure Spanish race in New Spain to consist of 1,200,000.

extinction, unless fresh blood is sent from Europe. The extinction of the Spanish race in America was likewise predicted more than twenty years ago by Dr. Knox. There is no doubt that this result has been greatly owing to the mixture of Spanish and Indian blood.

The laws regulating the mixture of human races do not directly concern the question of acclimatization; it has been found, however, that there is a different vitality between the offspring of the Spaniard and the Indian female, from that between the Englishman and the Indian woman. So also there is a different power of life between the offspring of the Portuguese and English with the negro woman. It can hardly be questioned that the Spanish race, like all other dark Europeans, are better suited for warm climates than the white Europeans. M. Boudin gives some statistics to show that the Spaniards and Italians also suffered less in the Great Russian campaign. Perhaps this may be explained by other causes.

On several occasions the Spaniards have attempted to colonize the beautiful island, Fernando Po, but have entirely failed. The last trial was made in 1859, when three hundred and fifty colonists were sent out, provided with every necessary; but at the beginning of 1861 they had nearly all died, the few remaining returning home entirely broken down in health.

On the change effected in Europeans by a residence in Ceylon, Sir J. Emerson Tennent observes*, "The pallid complexion peculiar to old residents is not alone ascribable to an organic change in the skin from its being the medium of perpetual exudation, but in part to a deficiency of red globules in the blood, and mainly to a reduced vigour in the whole muscular apparatus, including the action of the heart, which imperfectly compensates by increase of rapidity for diminution of power." This author very properly warns all habitual dyspeptics from a long sojourn at Ceylon. Gouty patients are, however, owing to the greater cutaneous excretion, entirely cured. We find that Europeans die mostly of cholera and inflammation of the liver, while negroes die of pulmonary consumption. Ceylon is hot for Europeans, and cold, especially in the forests, in comparison to the coast of Guinea.

Of the island of Cuba, Mr. Tylor has just written†, "The climate of the island is not unfavourable for a mixed negro and European race, while to the pure whites it is deadly. It is only by intermarriage with Europeans, and continual supplies of emigrants from Europe, that the white population is kept up."

In the Reports of the Colonies for 1858 and 1859, we only find the births and deaths of the different populations of one colony given. From these we learn that, at Antigua, in

1858	the births of	white	population were	50	deaths	75
1859	„	„	„	91	„	140
1858	„	black	„	952	„	979
1859	„	„	„	1005	„	894
1858	„	coloured	„	238	„	226
1859	„	„	„	250	„	205

Although this classification (of white, black, and coloured)‡ is not very scientific, yet it would be of very great utility to get such simple returns from all our colonies, with the percentage of women.

Our experience of other races than the European is limited. Mr. Crawfurd contends that the Chinese become easily acclimatized in nearly all re-

* Loc. cit. p. 78.

† Anahuac; or, Mexico and the Mexicans. By Edward B. Tylor, 1861, p. 12.

‡ The coloured population are sometimes called brown. These terms are generally used to signify a mongrel breed of some sort.

gions; and Pruner-Bay says "that the Turanian is, in physical respects, the true cosmopolite."

I have already stated that latitude is no test of climate; so I would now state, that as neither heat nor cold is the cause of the physical differences of mankind, so neither is it mere heat or cold which affects man injuriously. That the Chinese have a large range of temperature is true, but they have not the great power of being acclimatized that many imagine. Fifty thousand Chinese have gone to Australia, and the same number to California; and perhaps about twenty or thirty thousand to Cuba, and six thousand to the Mauritius. This is a misfortune for both Australia and California; but there is hope for Cuba, as the Chinese are said not to be able to work there. Mr. Tylor says*, "Fortunately for them, they cannot bear the severe plantation-work. Some die after a few days of such labour and exposure, many more kill themselves; and the utter indifference with which they commit suicide, as soon as life seems not worth having, contributes to moderate the exactions of their masters. A friend of ours in Cuba had a Chinese servant who was impertinent one day, and his master turned him out of the room, dismissing him with a kick. The other servants woke their master early next morning with the intelligence that the Chinese had killed himself in the night to expiate the insult he had received."

We are at present quite unable to say whether the Chinese will ever become acclimatized in California or Australia. It is to be hoped, however, that they will not be able. The Chinese have taken no women with them to either place; but in Australia some of them are living with native women, and this may be the means of producing a hybrid race of Chinese-Australians. Whether this may stay the current of extinction which seems settling on the Australians, or whether it may aid in their destruction, are questions beyond the limits of this paper. Of the Indian immigrants to the Mauritius, we learn that the deaths exceeded the births by three hundred and eleven, but we are not told of the percentage of women.

The mortality generally of the colony was—

In 1854	7	per cent.
1855	3·5	,,
1856	5·0	,,
1857	2·5	,,
1858	2·7	,,

In Trinidad, the total Indian population was, in 1859, thirteen thousand four hundred and forty-seven, and the deaths 2·7 per cent.; but amongst the arrivals from Madras, the mortality was 7·7 per cent.

In 1859, the mortality of the Calcutta coolies was 2 per cent.

Of the Malays all we know is, that the Dutch took some to the Cape, and the race still remains there, but whether pure or mixed we know very little; we also are not informed if their numbers are increasing or decreasing. Of the Red Indians we only know that, on being removed from their native soil, they soon perish: it is uncertain how much of this must be ascribed to the climate, or how much to the inability of the race to alter their manners and customs.

The royal family of the Sandwich Islands who visited England in 1827 all died, as did most of their attendants, of tubercular disease, after only three months' visit.

So the Andaman Islander taken to Calcutta by Dr. Mouat was soon affected by the climate, and obliged to be returned to his native land to save his life.

* Loc. cit. p. 13.

But perhaps the negroes offer the strongest proof of the fallacy of saying that all races of men are cosmopolitan. We have ample and positive evidence that they cannot perpetuate themselves beyond about the fortieth degree of north or south latitude. Indeed, in their own region the ascent of a high mountain will kill them, sometimes nearly instantly. Thus, out of the eight Africans who ascended with Beecroft the Saint Isabel Mountain*, at Fernando Po, no less than five died.

The negro seems to thrive in the southern states of America; but it is far from probable that he is suited to all tropical countries. Sir A. Tulloch and Dr. Bennett Dowler coincide in opinion that the negro will die out in the West Indies and the Mauritius. At Cuba, Mr. Tylor says†, "there are fifteen thousand slaves imported annually;" he also adds, "that the Creoles of the country are a poor degenerate race, and die out in the fourth generation." The race is only kept up in Egypt and Algiers by constant immigration.

In the Mauritius, the deaths in five years exceeded the births by upwards of six thousand, in a population of sixty thousand.

Dr. Boudin says, "In Ceylon, in 1841, there was not a trace of the nine thousand negroes imported by the Dutch government before the English domination. Of the five thousand negroes imported by the English since 1803, there remained only, in 1841, about two hundred to three hundred, although females were imported to preserve them."

Of the 4th West Indian Regiment placed, in 1819, in garrison at Gibraltar, nearly all perished of pulmonary disease in fifteen months.

The statistics of the mortality of negroes in the different States have clearly shown the influence of climate. The farther they go north, the higher becomes the rate of mortality; they seem to die of consumption, just like the monkeys and lions in the Zoological Gardens.

It is difficult to determine the exact amount of influence exerted by race in resisting particular diseases. It has, however, been shown that the negro race on the West Coast of Africa, especially, is exempted from yellow fever, and that a very small portion of African blood is sufficient to resist the influence of this disease.

All the dark races seem less liable to yellow fever than the white man. Both the Red Indian and the Southern European are more exempt than the Englishman.

Mr. Clarke‡ says, that when the yellow fever broke out at Sierra Leone in 1837-8-9, 1847, and 1859, he never knew of a single negro or even of a man of mixed blood being attacked. He also says, that in 1837 and 1839 small-pox broke out among the negroes, and disappeared at the same times as the yellow fever appeared. With the plague the dark races are affected far more than the white, being the reverse of the law with the yellow fever. Dr. Nott contends that the predisposition to yellow fever is just in proportion to the lightness of the skin; and that with plague the reverse is the case.

The Jewish race, and not the Chinese race, are, however, nearest to being cosmopolitan. It is asserted that they live and thrive all over the world. If, however, we come to examine the evidence of this fact, we find that many of the people reputed to be Jews have no claim whatever to that questionable honour; such, for instance, as the many reputed cases of black Jews.

Dr. Boudin, although an advocate for the non-cosmopolitan powers of

* The greatest height at which this mountain was ever estimated was that by Consul Hutchinson, who thought it was twelve thousand feet.

† Loc. cit. p. 12.

‡ Remarks on the Topography and Diseases of the Gold Coast, p. 28.

man generally, makes an exception in favour of the Jewish race, and says that this race has settled the question that one race is cosmopolitan.

The statistics which have been published respecting the Jews in different countries seem to show that the Jew is subject to different physiological laws from those of the people by whom he may be surrounded. This phenomenon may, however, be explained by other physiological laws. M. Boudin supports his views from the difference in the statistics of disease and death of the Jews and the other colonists in Algeria. But the conditions of these two are very different. The Jews have been in Algeria for a considerable time, while the colonists are going there daily. Had M. Boudin proved that a number of Jews and Frenchmen went to Algeria at the same time, and that the Jews became more easily acclimatized, it might go some way towards showing the advantage of the Jewish race over the Frenchman, if we could not explain the phenomenon on other grounds. Had M. Boudin proved satisfactorily that the Jew was cosmopolitan, we should not easily be induced to admit that this was inexplicable by physiological laws. I do not pretend to enter into any of the causes which may have enabled the Jew to appear favoured; but we must not hurriedly admit that there are exceptional laws in favour of any one race. On the same plea that M. Boudin has claimed an exception in favour of the Jews, we may also advocate one on the part of the Gipsies. The chief cause, however, of the apparent superiority of the Jews over some other races is the fact that they are a pure race. All pure races support the influence of change better than mixed races. The nomadic Arabs, as long as they remain pure, can also live in very different temperatures and climates. The Chinese are also generally a pure race; and it is possible that the nearer the race approach the original type, the greater power they have in enduring change of climate. But enduring change of climate is not acclimatization. A process of acclimatization should enable a race to perpetuate itself in a new region, without supplies of new blood from its own region, and without, of course, mixing with the indigenous races of the invaded country. The recorded historical migrations of nations do not give us sufficient evidence to make us believe in different laws from those which are in existence at this time.

I am fully sensible of the great difficulty there is at present of defining the exact limits of the various ethnic centres. When I speak therefore of the European centre, I would also observe that this region is not necessarily confined to the portion of the earth we call Europe; on the contrary, I should include the whole of those original inhabitants of the Mediterranean, such as the Phœnicians, as belonging to the European centre. The modern Jews*, for instance, who are most probably lineal descendants of the old Phœnician merchants, are vastly superior to any purely Asiatic race. Never was the Jew more calumniated than by saying that he is an Asiatic! We all know the distinctive characteristics of the various Asiatic races, and nowhere do we find a people at all resembling the Jews. The only explanation I have ever heard given of this contradiction is that by Mr. Burke. That gentleman contends that there is a hierarchy not only in ethnic centres, but similarly in their climates; and that any race coming from an inferior centre to a higher centre is thereby improved, other conditions being equal, and provided of course that the change be not too violent. Thus he points out the fact that the Jew has not degenerated in Europe, but has greatly improved in spite of all disadvantages. He also very truly observes, that no one will contend that the climate of Palestine will suit an Englishman as

* I do not include in this term the fair-haired, blue-eyed race found in the Levant, and who are called Jews by Mr. Layard and Dr. Beddoe.

that of England suits a Jew. We have, however, evidence to show that the climate of Palestine *does not* suit a Jew—a pretty good test that it is not his native land. Many writers have noticed this; but I will only quote the impartial evidence of Eliot Warburton, who says*, "It is a curious but well-ascertained fact that the Jews do not multiply at present in the native city of their race; few children attain to puberty, and the mortality altogether is so great, that the constant reinforcements from Europe scarcely maintain the average population."

The great majority of the Jewish race is in Europe. The entire number of Jews, according to M. Boudin, is computed to be four millions three hundred thousand; and of these there are in Europe three millions six hundred thousand, in Africa four hundred and fifty thousand, in Asia two hundred thousand, America forty-eight thousand, and in Australia two thousand. Thus, more than three-fourths of the entire number of Jews are in Europe, and only a fraction of $\frac{2}{43}$ in Asia. Mr. Burke conceives it possible that even the Negro might be improved in the long run by coming to Europe under favourable circumstances, "though this," says Mr. Burke, "would not apply to the lower and unprogressive portions of the type, but to its advancing sections." Our researches have rather tended to show, however, that although they may not degenerate like Europeans going to an inferior centre, they still are incapable of becoming acclimatized anywhere in Europe, and we much doubt if even out of Africa. We are unable, in the present state of our science, *to do more than see that ethnic centres do exist, without being able to define their exact limits or their number.*

In a former part of this paper I incidentally touched on the influence of the mind in conquering physical agents. Maltebrun, Goethe, and Kant have all given their testimony in favour of the power of the mind in resisting disease. And this subject becomes important with reference to some statistical facts respecting the difference in mortality between the officers and men in India and elsewhere. Thus, with bowel-complaints in India, there were in Bengal only three more deaths of European officers in a ratio of ten thousand than in the same number of sepoys; and in Madras eighteen fewer deaths took place than in a similar number of sepoys†. Dr. Cameron also affirms that the ravages of cholera did not affect the officers or other Europeans in a like grade of life; and he says that "the small mortality amongst the officers of European regiments in Ceylon is very remarkable‡." Indeed, the whole medical records teem with instances of the influences which the mind possesses in the production and removal of disease. It is possible that much may be done to enable our troops to exist in India and elsewhere by attention to the necessity that exists for mental as well as physical exercise. Much might also be effected were the differences of temperaments more studied, and a judicious selection made of those fitted for hot, and those for cold, climates.

Two questions were asked Sir Ranald Martin, who is a great advocate for hill-stations and for other reforms in the army; his answers§ are important.

"1st. But is there no such thing as acclimatization?

"A. No, I believe not.

"2nd. Physically, you do not think that acclimatization exists?

"A. I think it does not."

These answers express the result of my own inquiries into this subject.

I have endeavoured to show from such facts as are at hand that man

* The Crescent and the Cross, 1851, eighth edition, p. 334.

† Ewart, p. 122.

‡ A note in Sir E. Tennent's 'Ceylon,' p. 82.

§ Minutes of Evidence, 'On the Reorganization of the Indian Army,' p. 172.

cannot be *rapidly* displaced from one region and located in another without injury. This must be admitted; but it may be answered that it can be done *slowly*—that if it cannot be done in one generation, it may be done in time. Now it is quite evident that "time is no agent" in this case; and unless there is some sign of acclimatization in one generation, there is no such process. A race may be living and flourishing in its own centre, but sometimes a very slight change into a new region will produce the most disastrous results. The Spaniards, for instance, cannot with impunity migrate into the new region on the opposite coast. In Egypt we see exemplified perhaps the most remarkable proof of what I have stated. From time immemorial Egypt has been ruled by foreign races, but not one has left any descendants. Mr. Warburton* has briefly expressed himself on this point in these words:—"The Turk never or rarely intermarries with Egyptians, and it is a well-known fact that children born of other women in this country rapidly degenerate or die; there are few indigenous Turks in Egypt. Through the long reign of the Mamelukes there was not one instance, I believe, of a son succeeding to his father's power and possessions." These Mamelukes were generally adopted Circassian slaves, who adopted others in their turn; and they had plenty of Circassian women imported to perpetuate their race, but with no better results than have met all other invaders. Of the English residents at Cairo the same writer observes, "The English seem to succumb, for the most part, to the fatal influence of this voluptuous climate, and, with some admirable exceptions, do little credit to the proud character of their country."

The English also, when sent to any part of the Mediterranean, suffer far more than in England. It has been proposed to locate British troops at these stations for a time, before they proceed to India. The caution that a warm climate requires change of habits might do good; but we strongly suspect that if troops were located in the Mediterranean for a few years before proceeding to India, the mortality would be far higher when they arrived there. If also, with a view of colonizing India, we were to send a colony, for a generation or more, to dwell in the Mediterranean, we should get a degenerate race who would have few of the qualities of the British race. Wherever we go, we may apply the question in a similar manner. The distribution of mankind over the globe is the result of law, order and harmony, and not of mere chance and accidental circumstances, as too many would have us believe. From the earliest dawn of history, races of men existed very much as they do now, and in the same locations. Jewish history, both monumental and written, tells us that the Jew has not changed for the last three thousand years; and the same is the case with all other races who have kept their blood pure. I would therefore say that it is as difficult to plant a race out of its own centre, as it is to extinguish any race without driving it from its natural centre. The Tasmanians and American Indians have both been extinguished by removal from their native soil; and this is nearly the only process yet discovered of extinguishing any race of man. The object of this paper, however, is simply to suggest to ethnologists and geographers the necessity of a further investigation of the important question of acclimatization.

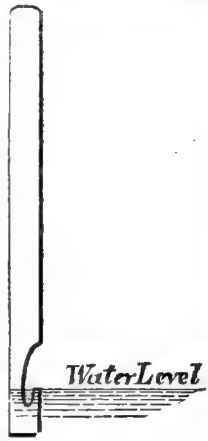
* Loc. cit. p. 67.

On Experiments on the Gauging of Water by Triangular Notches. By JAMES THOMSON, *M.A., Professor of Civil Engineering, Queen's College, Belfast.*

IN 1858 I presented to the Association an interim Report on the new method which I had proposed for the gauging of flowing water by triangular (or V-shaped) notches, in vertical plates, instead of the rectangular notches, with level bottom and upright sides, in ordinary use. I there pointed out that the ordinary rectangular notches, although for many purposes suitable and convenient, are but ill adapted for the measurement of very variable quantities of water, such as commonly occur to the engineer to be gauged in rivers and streams; because, if the rectangular notch be made wide enough to allow the water to pass through it in flood times, it must be so wide that for long periods, in moderately dry weather, the water flows so shallow over its crest, that its indications cannot be relied on. I showed that this objection would be removed by the employment of triangular notches, because, in them, when the quantity flowing is small, the flow is confined to a narrow and shallow space, admitting of accurate measurement; and as the quantity flowing increases, the width and depth of the space occupied in the notch increase both in the same ratio, and the space remains of the same form as before, though increased in magnitude. I proposed that in cases in which it might not be convenient to form a deep pool of quiet water at the upstream side of the weir-board, the bottom of the channel of approach, when the triangular notch is used, may be formed as a level floor, starting exactly from the vertex of the notch, and extending both up stream and laterally so far as that the water entering on it at its margin may be practically considered as still water, of which the height of the surface above the vertex of the notch may be measured in order to determine the quantity flowing. I indicated theoretic considerations which led to the anticipation that in the triangular notch, both without and with the floor, the quantity flowing would be proportional, or very nearly so, to the $\frac{5}{2}$ power of the height of the still-water surface above the vertex of the notch. As the result of moderately accurate experiments which I had at that time been able to make on the flow in a right-angled notch, without floor, I gave the formula $Q=0{\cdot}317\,H^{\frac{5}{2}}$, where Q is the quantity of water in cubic feet per minute, and H the head of water, as measured vertically, in inches, from the still-water level of the pool down to the vertex of the notch. This formula I submitted at that time temporarily, as being accurate enough for use for many ordinary practical purposes for the measurement of water by notches similar to the one experimented on, and for quantities of water limited to nearly the same range as those in the experiments (from about two to ten cubic feet per minute), but as being subject to amendment by future experiments which might be of greater accuracy, and might extend over a wider range of quantities of water.

Having been requested by the General Committee of the Association to continue my experiments on this subject, with a grant placed at my disposal for the purpose, I have, in the course of last summer and of the present summer, devoted much time to the carrying out of more extended and more accurate experiments. The results which I have now obtained are highly satisfactory. I am confident of their being very accurate. I find them to be in close accordance with the law which had been indicated by theoretical considerations; and I am satisfied that the new system of gauging, now by these experiments made completely ready for general application, will prove to be of great practical utility, and will afford, for a large class of cases, important advantages over the ordinary method—for such cases, especially, as the very varying flows of rivers and streams.

The experiments were made in the open air, in a field adjacent to a corn-mill belonging to Mr. Henry Neeson, in Carr's Glen, near Belfast. The water-supply was obtained from the course leading to the water-wheel of the mill, and means were arranged to allow of a regulated supply, variable at pleasure, being drawn from that course to flow into a pond, in one side of which the weir-board with the experimental notch was inserted. The inflowing stream was so screened from the part of the pond next the gauge-notch, as to prevent any sensible agitation being propagated from it to the notch, or to the place where the water level was measured. For measuring the water level, a vertical slide-wand of wood was used, with the bottom end cut to the form of a hook (as shown in the marginal figure), the point of which was a small level surface of about one-eighth of an inch square. This point of the hook, by being brought up to the surface of the water from below, gave a very accurate means for determining the water level, or its rise or fall, which could be read off by an index mark near the top of the wand, sliding in contact with the edge of a scale of inches on a fixed framing which carried the wand.



By other experimenters a sharp-pointed hook, like a fishing-hook, has sometimes, especially of late, been used for the same purpose, and such a hook affords very accurate indications. The result of my experience, however, leads me to incline to prefer something larger than the sharp-pointed hook, and capable of producing an effect on the water surface more easily seen than that of a sharp-pointed hook; and on the whole I would recommend a level line like a knife-edge, which might be from one-eighth to half an inch long, in preference either to a blunt point with level top or a sharp point. The blunt point which I used was so small, however, as to suit very perfectly. If the point be too large, it holds the water up too much on its top as the water in the pond descends, and makes too deep a pit in the surface as the water ascends and begins to flow over it. The knife-edge would be free from this kind of action, and would, I conceive, serve every purpose perfectly, except when the water has a sensible velocity of flow past the hook, and in that case, perhaps, the sharp point, like that of a fishing-hook, might be best.

To afford the means for keeping the water surface during an experiment exactly at a constant level, as indicated by the point of the wooden hook, a small outlet waste-sluice was fitted in the weir-board. The quantity of water admitted to the pond was always adjusted so as to be slightly in excess of that required to maintain the water level in the pond at the height at which the hook was fixed for that experiment. Then a person lying down, so as to get a close view of the contact of the water surface with the point of the hook, worked this little waste or regulating sluice, so as to maintain the water level constantly coincident with the point of the hook.

The water issuing from the experimental notch was caught in a long trough, which conveyed it forward with slight declivity, so as to be about seven or eight feet above the ground further down the hill-side, where two large measuring-barrels were placed side by side at about six feet distance apart from centre to centre. Across and underneath the end of the long trough just mentioned, a tilting-trough 6 feet long was placed, and it was connected at its middle with the end of the long trough by a leather flexible joint, in such a way that it would receive the whole of the water without loss, and convey it at pleasure to either of the barrels, according as it was tilted to one side or the other.

Each barrel had a valve in the bottom, covering an aperture six inches square, and the valve could be opened at pleasure, and was capable of emptying the barrel very speedily. The capacity of the two barrels jointly was about 230 gallons, and their content up to marks fixed near the top for the purpose of the experiments was accurately ascertained by gaugings repeated several times with two- or four-gallon measures with narrow necks.

By tilting the small trough so as to deliver the water alternately into the one barrel and the other, and emptying each barrel by its valve while the other was filling, the process of measuring the flowing water could be accurately carried on for as long time as might be desired. With this apparatus, quantities of water up to about 38 cubic feet per minute could be measured with very satisfactory accuracy.

The experiments of which I have now to report the results were made on two widths of notches in vertical plane surfaces. The notches were accurately formed in thin sheet iron, and were fixed so as to present next the water in the pond a plane surface, continuous with that of the weir-board.

The one notch was right-angled, with its sides sloping at 45° with the horizon, so that its horizontal width was twice its depth. The other notch had its sides each sloping two horizontal to one vertical, so that its horizontal width was four times its depth.

In each case experiments were made both on the simple notch without a floor, and on the same notch with a level floor starting from its vertex, and extending for a considerable distance both up stream and laterally. The floor extended about 2 feet on each side of the centre of the notch, and about $2\frac{1}{2}$ feet in the direction up stream, and this size was sufficient to allow the water to enter on it with only a very slow motion—so slow as to be quite unimportant. The height of the water surface above the vertex of the notch was measured by the sliding hook at a place outside the floor, where the water of the pond was deep and still.

The principal results of the experiments on the flow of the water in the right-angled notch without floor are briefly given in the annexed table, the

H.	Q.	*c*.
7	39·69	·3061
6	26·87	·3048
5	17·07	·3053
4	9·819	·3068
3	4·780	·3067
2	1·748	·3088

quantity of water given in column 2 for each height of 2, 3, 4, 5, 6, and 7 inches being the average obtained from numerous experiments comprised in two series, one made in 1860, and the other made in 1861, as a check on the former set, and with a view to the attainment of greater certainty on one or two points of slight doubt. The second set was quite independent of the first, the various adjustments and gaugings being made entirely anew. The two sets agreed very closely, and I present an average of the two sets in the table as being probably a little more nearly true than either of them separately. The third column contains the values of the coefficient c, calculated for the formula $Q=cH^{\frac{5}{2}}$, from the several heights and corresponding quantities of water given in the first and second columns, H being the height, as measured vertically in inches from the vertex of the notch up to the still-water surface of the pond, and Q being the corresponding quantity of water in cubic feet per minute, as ascertained by the experiments. It will be observed from this table that, while the quantity of water varies so greatly as from $1\frac{3}{4}$ cubic feet per minute to 39, the coefficient c remains almost absolutely constant; and thus the theoretic anticipation that the quantity should be proportional, or very nearly so, to the $\frac{5}{2}$ power of the depth is fully confirmed by experiment. The mean of these six values of c is ·3064; but, being inclined to give rather more weight, in the determination of the coefficient as to its amount, to some of the experiments made this year than to those of last year, I adopt ·305 as the coefficient, so that the formula for the right-angled notch without floor will be

$$Q = \cdot 305\ H^{\frac{5}{2}}.$$

My experiments on the right-angled notch with the level floor, fitted as already described, comprised the flow of water for depths of 2, 3, 4, 5, and 6 inches. They indicate no variation in the value of c for different depths of the water, but what may be attributed to the slight errors of observation. The mean value which they show for c is ·308; and as this differs so little from that in the formula for the same notch without the floor, and as the difference is within the limits of the errors of observation, and because some consecutive experiments, made without and with the floor, indicated no change of the coefficient on the insertion of the floor, I would say that the experiments prove that, with the right-angled notch, the introduction of the floor produces scarcely any increase or diminution on the quantity flowing for any given depth, but do not show what the amount of any such small increase or diminution may be, and I would give the formula

$$Q = \cdot 305\ H^{\frac{5}{2}}$$

as sufficiently accurate for use in both cases. The experiments in both cases were made with care, and are without doubt of very satisfactory accuracy; but those for the notch without the floor are, I consider, slightly the more accurate of the two sets.

The experiments with the notch with edges sloping two horizontal to one vertical showed an altered feature in the flow of the issuing vein as compared with the flow of the vein issuing from the right-angled notch. The edges of the vein, on issuing from the notch with slopes two to one, had a great tendency to cling to the outside of the iron notch and weir-board, while the portions of the vein issuing at the deeper parts of the notch would shoot out and fall clear of the weir-board. Thus, the vein of water assumed the appearance of a transparent bell, as of glass, or rather of the half of a bell closed in on one side by the weir-board and enclosing air. Some of this air was usually carried away in bubbles by the stream at bottom, and the remainder continued shut up by the bell of water, and existing under slightly less than atmospheric pressure. The diminution of pressure of the enclosed air was manifested by the sides of the bell being drawn in towards one another, and sometimes even drawn together, so as to collapse with one another at their edges which clung to the outside of the weir-board. On the full atmospheric pressure being admitted, by the insertion of a knife into the bell of falling water, the collapsed sides would instantly spring out again. The vein of water did not always form itself into the bell; and when the bell was formed, the tendency to the withdrawal of air in bubbles was not constant, but was subject to various casual influences. Now it evidently could not be supposed that the formation of the bell and the diminution of the pressure of the confined air could occur as described without producing some irregular influences on the quantity flowing through the notch for any particular depth of flow, and this circumstance must detract more or less from the value of the wider notches as means for gauging water in comparison with the right-angled notch with edges inclined at 45° with the horizon. I therefore made numerous experiments to determine what might be the amount of the ordinary or of the greatest effect due to the diminution of pressure of the air within the bell. I usually failed to meet with any perceptible alteration in the quantity flowing due to this cause, but sometimes the quantity seemed to be increased by some small fraction, such as one, or perhaps two, per cent. On the whole, then, I do not think that this circumstance need prevent the use, for many practical purposes, of notches of any desired width for a given depth.

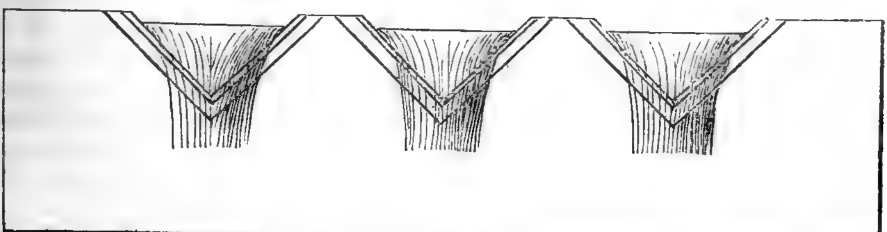
My experiments give as the formula for the notch, with slopes of two horizontal to one vertical, and without the floor,

$$Q=0{\cdot}636\ H^{\frac{5}{2}},$$

and for the same notch, with the horizontal floor at the level of its vertex,

$$Q=0{\cdot}628\ H^{\frac{5}{2}}.$$

In all the experiments from which these formulas are derived, the bell of falling water was kept open by the insertion of a knife or strip of iron, so as to admit the atmospheric pressure to the interior. The quantity flowing at various depths was not far from being proportional to the $\frac{5}{2}$ power of the depth, but it appeared that the coefficient in the formula increased slightly for very small depths, such as one or two inches. For instance, in the notch with slopes 2 to 1 without the floor, the coefficient for the depth of two inches came out experimentally 0·649, instead of 0·636, which appeared to be very correctly its amount for four inches' depth. It is possible that the deviation from proportionality to the $\frac{5}{2}$ power of the depth, which in this notch has appeared to be greater than in the right-angled notch, may be due partly to small errors in the experiments on this notch, and partly to the clinging of the falling vein of water to the outside of the notch, which would evidently produce a much greater proportionate effect on the very small flows than on great flows. The special purpose for which the wide notches have been proposed is to serve for the measurement of wide rivers or streams in cases in which it would be inconvenient or impracticable to dam them up deep enough to effect their flow through a right-angled notch. In such cases I would now further propose that, instead of a single wide notch, two, three, or more right-angled notches might be formed side by side in the same weir-board, with their vertices at the same level, as shown in the an-



nexed figure. In cases in which this method may be selected, the persons using it, or making comparisons of gaugings obtained by it, will have the satisfaction of being concerned with only a single standard form of gauge-notch throughout the investigation in which they may be engaged.

By comparison of the formulas given above for the flows through the two notches experimented on, of which one is twice as wide for a given depth as the other, it will be seen that in the formula for the wider notch the coefficient ·636 is rather more than double the coefficient ·305 in the other. This indicates that as the width of a notch, considered as variable, increases from that of a right-angled notch upwards, the quantity of water flowing increases somewhat more rapidly than the width of the notch for a given depth. Now, it is to be observed that the contraction of the stream issuing from an orifice open above in a vertical plate is of two distinct kinds at different parts round the surface of the vein. One of these kinds is the contraction at the places where the water shoots off from the edges of the plate. The curved surface of the fluid leaving the plate is necessarily tangential with the surface of the plate along which the water has been flowing, as an infinite force would be required to divert any moving particle suddenly out of its previous course*. The other kind of contraction in orifices open above consists in the sinking of the upper surface, which begins gradually within the pond or reservoir, and continues after the water has passed the orifice. These two contractions come into play in very different degrees, according as the notch (whether triangular, rectangular, or with curved edges) is made deep and narrow, or wide and shallow. From considerations of the kind here briefly touched upon, I would not be disposed to expect theoretically that the coefficient c for the formula for V-shaped notches should be at all truly proportional to the horizontal width of the orifice for a given depth; and the experimental results last referred to are in accordance with this supposition. I would, however, think that, from the experimental determination now arrived at, of the coefficient for a notch so wide as four times its depth, we might very safely, or without danger of falling into important error, pass on to notches wider in any degree, by simply increasing the coefficient in the same ratio as the width of the notch for a given depth is increased.

Appendix.—April 1862.

With reference to the comparison made, in the concluding sentences of the foregoing Report, between the quantities of water which, for any given depth of flow, are discharged by notches of different widths, and to the opinion there expressed, that we might, without danger of falling into important error, pass from the experimental determination of the coefficient for a notch so wide as four times its depth, to the employment of notches wider in any degree, by simply increasing the coefficient in the same ratio as the width of the notch for a given depth is increased, I now wish to add an investigation since made, which confirms that opinion, and extends the determination of the discharge, beyond the notches experimented on, to notches of any widths great in proportion to their depths. This investigation is founded on the formula for the flow of water in rectangular notches obtained from elaborate and careful experiments made on a very large scale by Mr. James B. Francis, in his capacity as engineer to the Water-power Corporations at Lowell, Massachusetts, and described in a work by him, entitled 'Lowell Hydraulic Experiments,' Boston, 1855†. That formula, for either the case in which there are no end-contractions of the vein, or for that in which the length of the weir is great in proportion to the depth of the water over its crest, and the flow over a portion of its length not extending to either end is alone considered, is

$$Q_1 = 3{\cdot}33\, L_1\, H_1^{\frac{3}{2}} \quad \ldots \quad (1)$$

where L_1 = length of the weir over which the water flows, without end-contractions; or length of any part of the weir not extending to the ends, in feet:

* This condition appears not to have been generally noticed by experimenters and writers on hydrodynamics. Even MM. Poncelet and Lesbros, in their delineations of the forms of veins of water issuing from orifices in thin plates, after elaborate measurements of those forms, represent the surface of the fluid as making a sharp angle with the plate in leaving its edge.

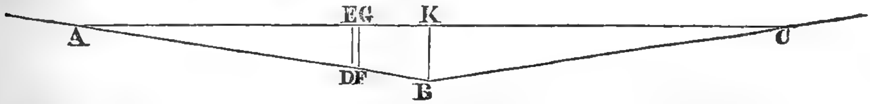
† The formula is to be found at page 133 of that work.

H_1=height of the surface-level of the impounded water, measured vertically from the crest of the weir, in feet:

and Q_1=discharge in cubic feet per second over the length L_1 of the weir.

It is to be understood that, in cases to which this formula is applicable, the weir has a vertical face on the upstream side, terminating at top in a level crest; and the water, on leaving the crest, is discharged through the air, as if the weir were a vertical thin plate.

To apply this to the case of a very wide triangular notch:—Let A B C be



the crest of the notch, and A C the water level in the impounded pool. Let the slopes of the crest be each m horizontal to 1 vertical; or, what is the same, let the cotangent of the inclination of each side of the crest to the horizon be $=m$. Let A E, a variable length, $=x$. Then E D$=\frac{x}{m}$. Let E G be an infinitely small element of the horizontal length or width from A to C. Then E G may be denoted by dx. Let q=quantity in cubic feet per second flowing under the length x, that is, under A E in the figure. Then dq will be the quantity discharged per second between E D and G F. Then, by the Lowell formula just cited, we have

$$dq=3{\cdot}33\,dx\left(\frac{x}{m}\right)^{\frac{3}{2}};$$

whence, by integrating, we get

$$q=3{\cdot}33\frac{1}{m^{\frac{3}{2}}}\cdot\tfrac{2}{5}x^{\frac{5}{2}}+C,$$

in which the constant quantity is to be put $=0$, because when $x=0$, q also $=0$. Hence we have

$$q=\tfrac{2}{5}\times3{\cdot}33\frac{1}{m^{\frac{3}{2}}}\cdot x^{\frac{5}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Let now H_2= height in feet from the vertex of the notch up to the level surface of the impounded water =B K in the figure. Then A K$=m\,H_2$. Let also Q_2 = the discharge per second in the whole triangular notch = twice the quantity discharged under A K. Then, by formula (2), we get

$$Q_2=\tfrac{4}{5}\times3{\cdot}33\times\frac{1}{m^{\frac{3}{2}}}(m\,H_2)^{\frac{5}{2}},$$

or

$$Q_2=2{\cdot}664\,m\,H_2^{\frac{5}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

To bring the notation to correspond with that used in the foregoing Report, let Q=the quantity of water in cubic feet per minute, and H=the height of the water level above the vertex in inches.

Then $Q_2=\frac{Q}{60}$, and $H_2=\frac{H}{12}$; and, by substitution in (3), we get

$$Q={\cdot}320\,m\,H^{\frac{5}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

This formula then gives, deduced from the Lowell formula, the flow in cubic feet per minute through a *very wide notch* in a vertical thin plate, when H is the height from the vertex of the notch up to the water level, in inches, and when the slopes of the notch are each m horizontal to 1 vertical.

As to the confidence which may be placed in this formula, I think it clear that, for the case in which the notch is so wide, or, what is the same, the slopes of its edges are so slight, that the water may flow over each infinitely small element of the length of its crest without being sensibly influenced in quantity by lateral contraction arising from the inclination of the edges, the formula may be relied on as having all the accuracy of the Lowell formula from which it has been derived; and I would suppose that when the notch is of such width as to have slopes of about four or five to one, or when it is of any greater width whatever, the deviation from accuracy in consequence of lateral contraction might safely be neglected as being practically unimportant or inappreciable.

This formula for wide notches bears very satisfactorily a comparison with the formulas obtained experimentally for narrower notches, as described in the foregoing Report. For slopes of one to one the formula was $Q = \cdot 305\ H^{\frac{5}{2}}$, and for slopes of two to one the formula was $Q = \cdot 636\ H^{\frac{5}{2}}$. To compare these with the one now deduced for any very slight slopes, we may express them thus:—

For slopes of 1 to 1	$Q = \cdot 305\, m\, H^{\frac{5}{2}}$
And for slopes of 2 to 1	$Q = \cdot 318\, m\, H^{\frac{5}{2}}$
While for any very slight slopes, or for any very wide notches, the formula now deduced from the Lowell one is	$Q = \cdot 320\, m\, H^{\frac{5}{2}}$.

The very slight increase from ·318 to ·320 here shown in passing from the experimental formula for notches with slopes of two to one, to notches wider in any degree—that slight change, too, being in the right direction, as is indicated by the *increase* from ·305 to ·318 in passing from slopes of one to one, to slopes of two to one—gives a verification of the concluding remarks in the foregoing Report; and this may serve to induce confidence in the application in practice of the formula now offered for wide notches.

Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops. By Dr. AUGUSTUS VOELCKER, *Royal Agricultural College, Cirencester.*

IN a Report read at the Aberdeen meeting, and subsequently printed in the 'Transactions of the British Association,' will be found recorded a number of field experiments on turnips and on wheat. Similar experiments upon these two crops have since been continued from year to year, and a new series of field experiments has been undertaken on the growth of barley.

In connexion with these field trials I have made numerous laboratory experiments on the solubility of the various forms and conditions in which phosphate of lime is likely to be presented to growing plants, and have likewise studied to some extent the influence of ammoniacal salts and a few other saline combinations on the solubility of the various forms in which phosphate of lime occurs in recent and fossil bones, in apatite, and other phosphatic materials.

The present Report will comprehend two sections. In the first I shall give the results of my field experiments on turnips, wheat, and barley; in the second section reference will be made to the solubility of phosphatic materials in various saline liquids.

1st *Part: Field Experiments.*

Before giving an account of recent experiments on turnips, wheat, and barley, not incorporated in the Report for 1859, it may appear desirable briefly to state the chief deductions that naturally flow from my previous experiments, extending over five seasons.

In these experiments I found that, amongst other particulars—

1. Ammoniacal salts, such as sulphate of ammonia, used alone, had a decidedly injurious effect upon the turnip crop, even when used in small quantities.

2. Purely ammoniacal manures applied to swedes at first checked the growth of the plant, and had ultimately no beneficial effect on the crop, either alone or in conjunction with phosphates.

3. Phosphates used alone, but in a readily available condition, produced a larger increase in the yield of turnips than mixtures of phosphates with ammoniacal matters.

4. Sulphates of potash and soda had no decided effect on turnips.

5. Sulphate of lime likewise was ineffective as a manure for turnips on the soil on which the experiments were tried.

6. On the other hand, ammoniacal manures, so inefficacious for root-crops, produced a considerable increase in the yield of wheat, grown on a soil similar to that of the experimental turnip-field.

7. Nitrate of soda, applied by itself, and still more so in conjunction with common salt, gave a very large increase per acre, both in straw and corn.

These are the principal results of previous field trials. Chemico-agricultural experiments, however, are of little or no practical utility, unless they are continued from year to year for a long period, and tried on a variety of soils, in good and in bad seasons, in a manner which allows us, if not to eliminate, yet clearly to recognize the disturbing influences of climate, season, condition of soils, and other circumstances which often affect the produce in a higher degree than the manures on which we experiment. A single field experiment is as likely to lead us in a wrong as in a right direction.

I have therefore continued field experiments similar to those already reported upon, and proceed with an account of field trials on turnips made in 1859.

Field Experiments on Swedish Turnips made in 1859.

The field selected for experimental trials in 1859 was in tolerably good condition. It bore clover in 1857, and wheat in 1858. The soil is moderately deep and well drained. A portion of the soil, taken from a large sample from different parts of the field, was submitted to analysis, and the following results obtained:—

Moisture (when analysed)	3·960
Organic matter and water of combination	9·616
Oxides of iron and alumina	19·660
Carbonate of lime	3·805
Sulphate of lime	·345
Phosphoric acid	·075
Magnesia	·783
Potash	1·239
Soda	·090
Insoluble siliceous matter (chiefly clay)	60·525
	100·098

This soil contained hardly any sand that can be separated by the mechanical process of washing and decantation. It contains, like most of the soils on our farm, an appreciable quantity of sulphate of lime and also of phosphoric acid. It is not so rich in carbonate of lime as many others of our fields, and is rich enough in clay to be called a good agricultural clay.

An acre of this land was divided into 20 parts. The different manures, after having been mixed with burnt soil for the sake of better distribution, were sown on the 6th of June, the land was ridged up, and the seed (Skirving's swedes) drilled on the following day. The distance between the drills was 22 inches; the plants were singled out 12 inches apart. The portion of the field on which the experiments were tried was left unmanured.

The following list exhibits the arrangement of the experimental field, the kinds of manure employed, and their quantities calculated per acre:—

Experiments upon Skirving's Swedes, in field No. 7, Royal Agricultural College Farm, Cirencester, 1859.

per acre.

Plot 1 was manured with 15 tons of rotten dung.

Plot 2 was manured with 15 tons of rotten dung and 2 cwt. of superphosphate.

Plot 3 was manured with 3 cwt. of superphosphate.

Plot 4 was manured with 1 cwt. of superphosphate.

Plot 5 was manured with 6 cwt. of superphosphate.

Plot 6 was manured with 3 cwt. of gypsum.

Plot 7 was manured with 2 cwt. of superphosphate and 1 cwt. of guano.

Plot 8 was manured with 3 cwt. of guano.

Plot 9 was manured with 1 cwt. of sulphate of ammonia.

Plot 10 was left unmanured.

Plot 11 was manured with 3 cwt. of fine bone-dust.

Plot 12 was manured with 2 cwt. of sulphate of ammonia.

Plot 13 was manured with 3 cwt. of turnip manure.

Plot 14 was manured with 1 cwt. of nitrate of soda.

Plot 15 was manured with 6 cwt. of turnip manure.

Plot 16 was manured with 3 cwt. of salt.

Plot 17 was manured with 3 cwt. of bone-ash treated with sulphuric acid.

Plot 18 was manured with 3 cwt. of dissolved bone-ash and 1 cwt. of sulphate of ammonia.

Plot 19 was manured with 3 cwt. of sulphate of potash.

Plot 20 was manured with 3 cwt. of dissolved bone-ash and 1 cwt. of nitrate of soda.

On each plot of the experimental field a remarkably even and good plant was obtained. The roots continued to grow as late as November; they were therefore left in the field until the 8th of December, when the crop was taken up. The roots were topped and tailed and cleaned, and the whole produce of each plat then carefully weighed, with the following results:—

Table showing the produce per acre of swedes, topped and tailed and cleaned, and increase per acre over the unmanured portion in field No. 7, Royal Agricultural College Farm, Cirencester, 1859.

Plot.	Manure.	Produce per acre. tons.	cwt.	qrs.	lbs.		Increase per acre. tons.	cwt.	qrs.	lbs.
1.	15 tons of farmyard manure	18	10	2	24	...	3	16	1	20
2.	15 tons of farmyard manure and 2 cwt. of superphosphate	17	6	3	4	...	2	12	2	0

Plot.	Manure.	Produce per acre. tons.	cwt.	qrs.	lbs.	Increase per acre. tons.	cwt.	qrs.	lbs.
3.	3 cwt. of superphosphate	17	11	2	10 ...	2	17	1	6
4.	1 cwt. of superphosphate	27	6	3	4 ...	2	12	2	0
5.	6 cwt. of superphosphate	21	2	3	12 ...	6	8	2	8
6.	3 cwt. of gypsum	16	14	1	4 ...	2	0	0	0
7.	2 cwt. of superphosphate and 1 cwt. of Peruvian guano	18	11	1	20 ...	3	17	0	6
8.	3 cwt. of Peruvian guano	18	17	2	20 ...	4	3	1	16
9.	1 cwt. of sulphate of ammonia ...	15	17	3	12 ...	1	3	2	8
10.	No manure	14	14	1	4 ...	0	0	0	0
11.	3 cwt. of fine bone-dust	18	9	2	16 ...	3	15	1	12
12.	2 cwt. of sulphate of ammonia ...	16	17	3	12 ...	2	3	2	8
13.	3 cwt. of turnip manure	20	1	1	20 ...	5	7	0	16
14.	1 cwt. of nitrate of soda	18	9	1	4 ...	3	15	0	0
15.	6 cwt. of turnip manure	20	7	0	16 ...	5	12	3	12
16.	3 cwt. of common salt	15	16	1	0 ...	1	1	3	24
17.	3 cwt. of dissolved bone-ash	20	15	2	24 ...	6	1	1	20
18.	3 cwt. of dissolved bone-ash and 1 cwt. of sulphate of ammonia	20	6	3	24 ...	5	12	2	20
19.	3 cwt. of sulphate of potash	17	0	2	4 ...	2	6	1	0
20.	3 cwt. of dissolved bone-ash and 1 cwt. of nitrate of soda	21	0	2	4 ...	6	6	1	0

In looking over the list of the different manures employed in these experiments, it will be noticed, in the first place, that certain simple salts which commonly enter into the composition of artificial manures have been used separately. It is not likely that we shall ever understand the action of complicated manures if we do not carefully study the separate effect of their component parts on vegetation. For this reason one plot was manured with sulphate of ammonia, another with sulphate of lime, a third with sulphate of potash, a fourth with chloride of sodium, and, finally, one with nitrate of soda.

In the next place, we have in Plot 17 phosphates chiefly in a soluble condition, and free from organic matter or anything else but sulphate of lime, which is necessarily produced when bone-ash is treated with sulphuric acid. In another plot (No. 18) we have the same materials in conjunction with sulphate of ammonia; and in No. 20 we have them united with nitrate of soda. Then with respect to the form in which the nitrogen is applied in these experiments, I would observe that we find it in farm-yard manure, partly as ready-formed ammonia, partly in the stage of semi-decomposed nitrogenized organic matter. In sulphate of ammonia it exists of course as a salt of ammonia; for nitrate of soda, we apply nitrogen in the shape of nitric acid. In guano nitrogen exists, partly, only in the form of ammoniacal salts,—the greater portion of nitrogen being present as uric acid and other organic compounds, which readily yield ammonia on decomposition. And lastly, we have all these different forms in which nitrogen can be conveniently applied to the land combined, together with phosphates, in the turnip manure.

The results of these experiments, though unsatisfactory in some respects, are nevertheless interesting and suggestive in others, and worthy of some comments.

Plot 1. Manured with 15 tons of farmyard manure per acre:—

	tons.	cwt.	qrs.	lbs.
Produce	18	10	2	24
Increase	3	16	1	20

Plot 2. Manured with 15 tons of farmyard manure and 2 cwt. of superphosphate per acre:—

	tons.	cwt.	qrs.	lbs.
Produce	17	6	3	4
Increase	2	12	2	0

In comparing the weight of roots from these two plots, it would appear that the additional quantity of supersulphate has had rather an injurious than a beneficial effect. We must, however, not entertain such a view, although the experiments before us appear to favour it; for the common experience of farmers is, that even well-manured land yields a better crop of swedes when the seed is drilled in with 2 or 3 cwt. of superphosphate of lime. I have reason for believing that on plot No. 1 more roots were grown than on plot No. 2; for I find the land on one side of the experimental plots yielded 17 tons 6 cwt. 1 qr. 20 lbs. per acre, and on the other side it gave 17 tons 18 cwt. 24 lbs. per acre. This land was manured with about 15 tons of farmyard manure and 3 cwt. of superphosphate per acre. This produce agrees well with the weight of the roots on the second plot, manured with dung and superphosphate. Still we have a difference of nearly 12 cwt. of roots in the two plots adjoining the experimental lots; and ought, therefore, to remember that the natural variations of the land, and other purely accidental circumstances, may readily give a difference in the produce of different portions of land which have been treated in every respect alike. Indeed, if the difference in the produce does not amount to more than 1 ton or even $1\frac{1}{4}$ ton, I fear we cannot do much with the results. It certainly would be rash to lay stress on such differences, and to use them as arguments in proving or denying the efficacy of certain manuring matters.

Plots 3, 4, and 5. Manured with superphosphate of lime.

The superphosphate used in these experiments had the following compositions:—

Manure	10·80
Organic matter*	4·21
Biphosphate of lime	20·28
Equal to bone-earth (rendered soluble)	(31·63)
Insoluble phosphates	4·11
Hydrated sulphate of lime	46·63
Alkaline salts (common salt chiefly)	10·78
Sand	3·19
	100·00

This superphosphate was chiefly made from bone-ash, and contained but very little nitrogen. We have thus here another proof that a good crop of roots can be obtained on clay land with superphosphate alone, containing but little nitrogenized or other organic matters.

Plot 7. Manured with Peruvian guano and superphosphate.

Plot 8. Manured with Peruvian guano.

The difference in the yield of these two plots is not more than 6 cwt., which is too insignificant to decide the question whether in the case before us Peruvian guano alone had a better effect upon the crop than the mixture of superphosphate and guano. In former years, however, I have found that Peruvian guano produced not nearly so great an increase as superphosphate alone, or a mixture of superphosphate and guano. There are, no doubt, soils for which guano is the most profitable manure, even for root-crops; but this is rather the exception, and not the rule.

On the soil of the experimental field, nitrogenized matters appear to have

* Containing nitrogen .... ·34
Equal to ammonia .... ·41

had a slight beneficial effect, which was not the case in the experiments which I tried on other soils in past years.

Plots 9 and 12. Manured with sulphate of ammonia.

The sulphate of ammonia used on Plot 12 has had a better effect on swedes than in former years. The effect, however, was not great when compared with that produced by phosphatic manures.

Plot 11. Manured with 3 cwt. of fine bone-dust.

Bone-dust, as might have been anticipated, gave a considerable increase. The bone-dust used in this experiment was very fine, it having been specially reduced to a coarse meal. On analysis it was found to consist of—

Moisture	10·58
Organic matter*	30·61
Phosphates of lime and magnesia	51·67
Carbonate of lime	6·03
Alkaline salts	·58
Sand	·53
	100·00

Plot 14. Manured with 1 cwt. of nitrate of soda.

I am not aware of any accurate experiments in which nitrate of soda has been used by itself for turnips. The effect which so small a quantity as 1 cwt. of nitrate of soda produced on the crop was decidedly beneficial, for it will be seen that as large a produce was obtained with 1 cwt. of nitrate of soda as with 3 cwt. of fine bone-dust. This result is certainly encouraging, and suggests a series of trials with nitrate of soda upon root-crops. The nitrate should be used in such trials by itself, as well as in conjunction with superphosphate or bones.

The nitrate of soda used in this experiment was a good sample, which contained 95·68 per cent. of the pure salt.

Plot 16. Manured with 3 cwt. of common salt.

Common salt, it will appear, has had little or no effect in this experiment; but it does not follow that it may not be beneficially applied to swedes, in conjunction with phosphatic fertilizers.

Plot 17. Manured with 3 cwt. of dissolved bone-ash.

In preparing this manure, 100 lbs. of good commercial bone-ash were mixed with 70 lbs. of brown sulphuric acid; and after some time this mixture was dried up with 50 lbs. of sulphate of lime. By this means an excellent superphosphate was obtained, as will be seen by the following analysis. The manure, being made of bone-ash, did not contain any ammoniacal salts nor appreciable quantities of nitrogen.

Composition of dissolved bone-ash.

Moisture	5·65
Organic matter	3·51
Biphosphate of lime	19·64
Equal to bone-earth rendered soluble	(30·65)
Insoluble phosphates	·86
Hydrated sulphate of lime	64·96
Alkaline salts	1·83
Sand	3·55
	100·00

* Containing nitrogen .... 3·71
Equal to ammonia .... 4·50.

The result of this plot affords another proof that a good crop of swedes may be obtained with a superphosphate in which all the phosphates are rendered soluble, and which contains no nitrogenized matters.

Plot 18. Manured with 3 cwt. of dissolved bone-ash and 1 cwt. of sulphate of ammonia.

In this experiment the addition of sulphate of ammonia to dissolved bone-ash appears to have done no good whatever.

Plot 19. Manured with 3 cwt. of sulphate of potash.

The sulphate of potash used in this experiment was a good commercial sulphate. It produced about the same increase as 2 cwt. of sulphate of ammonia; and, in comparison to the effect which phosphatic manures produced, must be considered as a manuring constituent which did not seem to be required on the soil on which the experiments were tried.

Plot 20. Manured with 3 cwt. of dissolved bone-ash and 1 cwt. of nitrate of soda.

The addition of nitrate of soda to the dissolved bone-ash gave only 14 cwt. more roots than the dissolved bone-ash used by itself—a quantity far too small to be regarded as a proof that nitrate of soda increased the efficacy of the dissolved bone-ash. From the preceding experiments I think we may safely draw the following conclusions:—

1. They point out in the most decided manner the great superiority of phosphatic matters as manuring constituents for root-crops.
2. It appears that a sufficient quantity of soluble phosphates renders other fertilizing matters superfluous on soils that have a constitution similar to that of the experimental field.
3. Ammoniacal salts do not appear to have any specific effect on the turnip-crop.
4. Alkaline chlorides and sulphates produced no effect.
5. Nitrate of soda had a beneficial effect upon the turnips.
6. Sulphate of lime was inefficacious as a fertilizer for swedes in the experimental field.

Wheat Experiments made in 1860.

The field on which the experiments were tried is quite level. It contains numerous fragments of oolitic limestones, no sand, and a large proportion of clay. The depth of the cultivated soil is about 9 inches on an average. The surface soil was well cultivated; it passes by degrees into limestone-rubble mixed with clay, and then rests on the great oolite limestone-rock. Two acres of this field were accurately divided into 8 plots, measuring $\frac{1}{4}$ of an acre each.

Plot 1 was manured with 4 cwt. of wheat manure per acre, specially prepared, being a mixed mineral and ammoniacal manure; cost £1 12*s*. per acre.

Plot 2 was manured with $2\frac{1}{2}$ cwt. of Peruvian guano per acre; cost £1 12*s*. 6*d*.

Plot 3 was manured with $1\frac{1}{2}$ cwt. of nitrate of soda; cost £1 10*s*. per acre.

Plot 4 was manured with $1\frac{1}{2}$ cwt. of nitrate of soda and 3 cwt. of common salt; cost £1 13*s*. per acre.

Plot 5 was manured with 3 cwt. of common salt per acre; cost 3*s*.

Plot 6 (unmanured).

Plot 7 was manured with 2 cwt. of sulphate of ammonia; cost £1 16*s*. per acre.

Plot 8 was manured with 32 bushels of soot per acre; cost 16*s*.

These manures were all sifted through a fine sieve and mixed with coal-ashes, so as to obtain, for the sake of better distribution, 20 bushels of the mixture. This was sown by broadcast distribution, on the 27th March, 1860.

The wheat dressed with nitrate of soda, and that dressed with nitrate of soda and salt, began to show the effects of these dressings four days after their application, by a much deeper green colour than could be observed on any of the other plots. After a week's time the wheat on the plot dressed with sulphate of ammonia, next to the plot manured with guano, assumed a darker green colour; and lastly, the wheat on plot No. 1 turned darker green. There was a marked difference of the plots 5 and 6, dressed with salt and left unmanured, and the rest of the experimental plots. The nitrate of soda plots, throughout the growing season, looked more luxuriant and darker green than the rest; and the wheat here was rather taller than on the other plots. On plot 6, manured with salt, the wheat was shorter in the straw than on plot 5, where no manure was applied. The wheat-crop was reaped in the last week of August, and thrashed out on the 27th of September, 1860.

The guano used as a top-dressing was genuine Peruvian guano of best quality.

The nitrate of soda contained 95¾ per cent. of pure nitrate.

In the commercial sulphate of ammonia I found 96½ per cent. of pure sulphate, and in the soot 2½ per cent of ammonia.

The wheat manure was the same as that employed in my experiments made in 1859, and contained in 100 parts—

Moisture	13·60
Sulphate of ammonia*	10·97
Soluble organic matter†	8·08
Insoluble organic matter†	14·72
Biphosphate of lime	3·54
Equal to bone-earth rendered soluble ...	(5·52)
Insoluble phosphates (bone-earth)	9·45
Sulphate of magnesia	·61
Hydrated sulphate of lime	19·73
Sand	2·46
	100·00

The following table gives the yield in corn and straw of each experimental plot, the manures employed, and the produce calculated per acre.

Manures employed, and sown March 27, 1860.	Produce thrashed out, September 24, 1860.
Plot 1. Mixed mineral and ammoniacal wheat-manure, 4 cwt. per acre.	Grain, 2480 lbs., or 42 bushels 2 lbs.; calculated at 59 lbs. per bushel. Straw 1 ton 13 cwt. 1 qr. 20 lbs.
Plot 2. Peruvian guano, 2½ cwt. per acre.	Grain, 2720 lbs., or 46 bushels 6 lbs.; weight of bushel, 59 lbs. Straw, 1 ton 16 cwt. 12 lbs.
Plot 3. Nitrate of soda, 1½ cwt. per acre.	Grain, 2576 lbs., or 44 bushels 10 lbs. Straw, 1 ton 17 cwt. 3 qrs. 16 lbs.
Plot 4. Nitrate of soda and salt, 1½ cwt. and 3 cwt.	Grain, 2804 lbs., or 47 bushels 31 lbs., at 59 lbs. per bushel. Straw, 1 ton 19 cwt. 3 qrs. 24 lbs.

* Containing nitrogen .... 2·32
Equal to ammonia .... 2·82

† Containing nitrogen .... 3·53
Equal to ammonia .... 4·28

Manures employed, and sown March 27, 1860.	Produce thrashed out, September 24, 1860.
Plot 5. 3 cwt. of common salt.	Grain, 2080 lbs., or 35 bushels 15 lbs., at 59 lbs. per bushel. Straw, 1 ton 3 cwt. 3 qrs. 16 lbs.
Plot 6. Unmanured.	Grain, 2004 lbs., or 33 bushels 57 lbs., at 59 lbs. per bushel. Straw, 1 ton 7 cwt. 20 lbs.
Plot 7. Sulphate of ammonia, 2 cwt. per acre.	Grain, 2596 lbs., or 44 bushels, at 59 lbs. per bushel. Straw, 1 ton 18 cwt. 8 lbs.
Plot 8. 32 bushels of soot.	Grain, 2460 lbs., or 41 bushels 41 lbs., at 59 lbs. per bushel. Straw, 1 ton 13 cwt. 3 qrs. 24 lbs.

This tabular statement of results suggests the following remarks :—

1. The natural produce of this field, it will be seen, amounted to nearly 34 bushels. The grain on all plots was lighter than it is usually, and weighed only 59 lbs. per bushel.

2. Nitrate of soda and salt produced the greatest increase in grain and straw—a result well corresponding with the results obtained in 1859. In grain we have an increase of 13 bushels per acre, and in straw an increase of 12 cwt. 3 qrs. 4 lbs., upon the unmanured portion of the field.

This large increase was obtained with an expenditure of £1 13*s.* per acre—an outlay which, even at a lower market-price of wheat, paid excellent interest.

3. Nitrate of soda applied by itself was not quite so beneficial, but still gave a large increase both of grain and straw.

4. Chloride of sodium, or common salt, on the other hand, hardly increased the yield in grain, and slightly reduced the yield in straw.

Common salt certainly has the effect of checking the growth of wheat, and is therefore frequently employed in cases in which the wheat is too luxuriant or, as it is called by farmers, too proud-looking. Such wheat has a tendency to fall down before the grain is quite ripe, especially if the season happens to be wet and stormy. Common salt is used by farmers for the purpose of preventing the laying of wheat, and is said to strengthen the straw. It does so, not by supplying to the wheat-plant a constituent deficient in the soil, but by retarding the abundant development of the halm of wheat and other cereals.

5. Next to nitrate of soda, Peruvian guano was the most efficacious and most economical manure for wheat. 2½ cwt. per acre gave an increase of 12 bushels of wheat over the unmanured portion, besides an increase of 9 cwt. of straw.

6. 2 cwt. of sulphate of ammonia per acre, applied by itself, gave a larger increase than 4 cwt. of a mixed mineral and ammoniacal manure, containing less ammoniacal and more mineral compounds than the 2 cwt. of sulphate of ammonia.

Thus, the latter gave an increase of 10 bushels of grain and 11 cwt. of straw, whilst the mixed mineral and ammoniacal manure gave only an increase of 8 bushels of grain and 6 cwt. of straw, in round numbers.

Field Experiments on Barley made in 1860.

Precisely the same experiments as those made upon wheat were tried on barley. Two acres of the barley-field were divided into plots of ¼ of an acre each, and the various top-dressings sown by manure distributor on the 25th of April.

The soil of this field is considered a good barley soil. It is full of limestone, gravel, and fragments of oolitic stones of larger size, and, like most soils in the neighbourhood of Cirencester, contains much clay. On analysis it gave—

Manure	10·254
Organic matter and matter of combination	6·947
Oxides of iron and alumina	12·754
Phosphoric acid	·659
Carbonate of lime	18·640
Sulphate of lime	·397
Magnesia	·195
Potash	·967
Soda	·309
Silica (soluble in dilute caustic potash)	14·018
Insoluble siliceous matter and loss (chiefly clay)	34·864
	100·000

The following tabular statement embodies the yield in grain and straw which the several plots furnished.

Produce of Corn and Straw.—Experiments with top-dressings on Barley.

	Grain. At 56 lbs. per bushel.			Straw.		
	lbs.	bush.	lbs.	cwt.	qrs.	lbs.
No. 1. Mixed mineral and ammoniacal manure, 4 cwt. per acre; cost £1 12*s.*	2524	45	4	22	2	16
No. 2. Peruvian guano, 2½ cwt. per acre; cost £1 12*s.* 6*d.*	2432	43	24	21	2	8
No. 3. Nitrate of soda, 1½ cwt. per acre; cost £1 10*s.* per acre.	2758	49	14	24	3	0
No. 4. Nitrate of soda 1½ cwt., and 3 cwt. of common salt; cost £1 13*s.*	2706	48	18	23	3	16
No. 5. 3 cwt. of salt per acre; cost 3*s.*	2308	41	12	16	2	0
No. 6. Nothing	2174	38	46	12	2	12
No. 7. Sulphate of ammonia, 2 cwt. per acre; cost £1 16*s.*	2642	47	10	22	0	22
No. 8. Soot, 32 bushels per acre; cost 16*s.*	2688	44	4	20	2	26

These barley experiments, on the whole, gave results corresponding to the results obtained in the wheat experiments. Thus, the plots dressed with nitrate of soda gave the largest increase, and sulphate of ammonia used alone gave a larger increase than the mixed mineral and ammoniacal manure.

The results do not, it is true, exactly agree in all particulars; but perfect agreement cannot be expected in field-experiments.

Thus, in the barley experiments, guano appears to have produced a less favourable result than in the wheat experiments, whilst the mixed mineral and ammoniacal manure appeared to be better adapted for barley than for wheat.

Whether this was the case, or whether the apparent differences in the effects of the same dressings on barley and wheat were due to differences in the composition and condition of the soil of the experimental fields, I am unable to decide.

The preceding experiments, I think, furnish convincing proofs that, through the instrumentality of purely nitrogenous manures, the produce of our grain-crops may be very considerably increased, whilst the same manures appear to be of no beneficial effect upon root-crops, at least on soils similar in character to those on which the experiments were made.

In making this statement, it is not maintained that mineral matters are less essential to cereals than to root-crops; for I take it for granted that no chemist or vegetable physiologist at the present time will consider the ash-constituents of plants less essential for cereals than for turnips and other root-crops. No amount of nitrogenous manure can replace these earthy matters, which enter into the composition of all cultivated plants.

But, at the same time, it is a matter of experience that on many soils no reasonable amount of mineral fertilizing constituents will increase the yield of wheat or barley, whilst on these soils a moderate amount of a purely nitrogenous manure will contribute to a large increase in the amount of corn which can be raised from the same soils.

It is hardly necessary to say, that the larger increase, as a matter of course, removes more mineral matter from a land dressed with an ammoniacal or purely nitrogenous manure than from land not so treated; nor can it be denied that on sandy and naturally sterile soils the application of fertilizing materials containing exclusively nitrogen, in some form or the other, will tend to the rapid exhaustion of such soils; it is nevertheless a fact that the great majority of English soils are so rich in mineral matters that no fear need be entertained of the land becoming permanently deteriorated by the occasional use of nitrogenous matters on wheat-soils.

With respect to the combination in which nitrogen appears to be most generally assimilated by plants, and to be most grateful to wheat and barley, and probably to vegetation in general, I am of opinion that nitric acid is by far the most usual form in which nitrogen is taken up by plants. Nitrates certainly produce a more rapid and more energetic effect than ammoniacal salts on all plants which are benefited by nitrogenous matters.

Nitrates have been found, by Dr. Sullivan and by myself, in a great variety of plants, and may be detected without much difficulty in every arable soil, when a sufficiently large quantity of soil is operated upon. In porous limestones, and in soils containing chalk and gravel, ammoniacal salts appear to be readily transformed into nitrates; hence the constant presence of traces of nitric acid in the limestones of buildings, and of the occurrence of nitrates in more considerable quantities in the well-water of towns. During the period of the most energetic growth of plants, that is, during the summer season, the process of nitrification no doubt proceeds with greater rapidity in the soil than during autumn and winter; and, in all probability, the luxuriant growth of plants during summer is materially assisted by the greater proportion of nitrates in the soil. Ammoniacal salts certainly benefit vegetation, and so do nitrogenous organic matters, but it may be questioned whether these matters have not to be ultimately converted into nitrates before they can be of real utility to vegetation. Taking into account all the laborious experiments which have been made of late by Boussingault, by De Ville, and Dr. Gilbert and Mr. Lawes, with respect to the assimilation of nitrogen by plants, and bearing in mind agricultural experience and the results of direct manuring experiments, I think we shall find—

1. That there is sufficient evidence for regarding the free nitrogen of the atmosphere as incapable of supplying plants with food which they can utilize in forming albuminous matters.

2. That nitrogenous organic matters, such as hoofs, horn, wool, hair, and

similar substances, are slow-acting fertilizers, which have to be transformed into soluble combinations before they can benefit plants.

3. That ammoniacal salts are more energetic fertilizing matters, which, however, are fixed in the soil at first, and retained in it during the colder periods of the year, and which are gradually changed into nitrates and rendered soluble during the most active period of plant-growth.

4. That, in the shape of nitrates, nitrogen is not only the most active, but also the most abundant and common combination from which plants derive their nitrogen.

2nd Part: On the solubility of phosphate of lime in various forms of phosphate of lime and phosphate of magnesia, in pure distilled water, and in various saline solutions.

Solubility of various phosphatic matters in distilled water.

The amount of phosphate of lime which water is capable of taking up from different materials depends, amongst other circumstances, on the physical condition of the materials.

Thus, hard crystalline phosphatic materials, even when finely powdered and left a long time in contact with water, do not yield so much phosphate of lime to water as more porous substances in a shorter period.

In the following experiments, a considerable excess of the finely powdered materials was mixed with about half a gallon of cold distilled water, and repeatedly shaken up from time to time and left in contact with the water for a week, except otherwise stated. The clear liquid was then drawn off with a siphon, and filtered perfectly clear. A pint was then evaporated to dryness, the residue dissolved in as little hydrochloric acid as possible, then precipitated with ammonia, and in some instances the precipitated phosphates were redissolved and thrown down a second time with ammonia.

In experimenting with phosphatic minerals, it is not sufficient merely to evaporate the watery solution to dryness; for, besides phosphate of lime, water dissolves more or less carbonate of lime, magnesia, traces of alkalies, &c., which, added to the weight of the phosphate of lime, in many instances would give the latter far too high. In each case 2 pints of liquid were evaporated separately, and the following results obtained:—

	Amount of phosphate of lime ($3CaO, PO_5$) dissolved in 1 pint.		per gallon.
	Exp.	grs.	grs.
Pure tribasic phosphate of lime, precipitated, burnt, and finely ground	1st	·28	2·24
	2nd	·27	2·16
Pure tribasic phosphate of lime, precipitated and still moist	1st	·72	5·76
	2nd	·67	5·36
Pure bone-ash, made from the shank-bone of a horse, washed with water for a long time before trying the solubility in water. (This bone-ash was made of a very solid bone.)	1st	·13	1·04
	2nd	·17	1·36
	3rd	·14	1·12
	4th	·15	1·20

	Amount of tribasic phosphate of lime dissolved in 1 pint.		per gallon.
	Exp.	grs.	grs.
Commercial sample of American bone-ash	1st	·25	2·00
	2nd	·22	1·76

It will be seen that precipitated phosphate of lime in a moist condition is greatly more soluble in water than the same material dried, burnt, and then finely ground.

In the next place, I have experimented upon bones in various forms and conditions, as will be seen by the following data.

Shank-bones of ox, coarsely ground and long soaked in water before the experiment was begun. This bone-dust was very hard and close in texture. The first pint, which was evaporated to dryness and further treated as stated above, was removed from the bone-dust after the water had been in contact for 3 days. After that time 1 pint contained ·06 grs., or ·48 grs. per gallon, of phosphate of lime left for 12 days in contact with bone-dust; the 2nd pint produced ·10, or ·80 per gallon.

Commercial bone-bust	1st pint gave ·46, or 3·68 per gallon.
	2nd pint gave ·53, or 4·24 per gallon.
A very porous sample of commercial bone-dust, 7000 grs. of solution gave	·54, or 5·40 per gallon.

	Amount of phosphate of lime dissolved by 7000 grs. of solution;		by 1 gallon.
Boiled bones (the refuse of glue-makers)	·59	or	5·90
Boiled bones (the same sample, after it had become quite rotten by keeping 10 weeks in water)	·62	or	6·20
The pith of ox horns (sloughs rather decomposed)	1 pint gave ·67	or	5·36

It has been noticed already some years ago, by Professor Wöhler, that rotten bones yield to water more phosphate of lime than fresh ones. My experiments fully confirm this observation, and they moreover show that the more porous the bone, the more readily it yields phosphate of lime to water.

I may mention here that, some time ago, I examined the tank-water containing the drainings and washings of the kennels at Harlow. The drainings were highly offensive to the smell, although not much discoloured. An imperial gallon, filtered perfectly clear, on evaporation furnished 36·86 grs. of solid residue, and in this residue I found ·44 of phosphate of iron and 4·28 grs. of phosphate of lime, thus showing that phosphate of lime is soluble to a considerable extent in water charged with putrefying animal matter.

Phosphate of magnesia, and phosphate of magnesia and ammonia, are considerably more soluble than phosphate of lime, as will be seen by the following determinations:—

	Amount dissolved by 1 pint. Exp.	grs.		by 1 gallon. grs.
Phosphate of magnesia ($3\,MgO_1, PO_5$), burnt and finely ground	1st	·87	......	6·96
	2nd	·89	......	7·12
The same in moist condition	1st	1·78	......	14·24
	2nd	1·80	......	14·48
Phosphate of magnesia and ammonia ($2MgO, PO_5, NH_4O$), in moist condition	1st	1·62	......	12·96
	2nd	1·68	......	13·50

In the next place, I give the amount of phosphate of lime dissolved by distilled water from the following phosphatic materials:—

	In 1 pint. Exp.	grs.		In 1 gallon. grs.
Peruvian guano	1st	·30	......	2·46
	2nd	·33	......	2·64

	In 1 pint. Exp.	grs.		In 1 gallon. grs.
Kooria mooria guano	1st	·15	......	1·20
	2nd	·18	......	1·44
Sombrero phosphate, or crust guano	1st	·10	......	·80
	2nd	·11	......	·88
Monks Island phosphate	1st	·13	......	1·04
	2nd	·12	......	·96
Suffolk coprolites	1st	·09	......	·72
	2nd	·07	......	·56
Cambridgeshire coprolites	1st	·08	......	·64
	2nd	·07	......	·56
Estramadura phosphorite	1st	·10	......	·80
	2nd	·10	......	·80
Norwegian apatite	1st	·06	......	·48
	2nd	·05	......	·40
Norwegian apatite treated with water charged with carbonic acid	1st	·33	......	2·64
	2nd	·35	......	2·80

It will be seen that the harder and the crystallized phosphatic minerals yield a much smaller quantity of phosphate of lime to water than the more porous and amorphous materials.

Solubility of phosphate of lime in solutions of sal ammoniac.

The solution of sal ammoniac employed in the following experiments contained 1 per cent. of sal ammoniac. A large excess of phosphate of lime was placed in a bottle and repeatedly shaken with a solution of sal ammoniac. After a lapse of seven days the clear liquid was drawn from the undissolved phosphate of lime and filtered; 1 pint was then evaporated to dryness and heated; the residue was dissolved in a few drops of HCl, and the solution precipitated with ammonia.

In the same manner the experiments with bones, bone-ash, and Cambridgeshire and Suffolk coprolites were executed, and the following results obtained:

Amount of phosphate of lime dissolved by water containing 1 *per cent. of sal ammoniac in solution.*

	1 pint contained, Exp.	grs.		Calculated per gallon. grs.
Precipitated phosphate of lime ($3\,CaO, PO_5$), still moist	1st	2·77	......	22·16
	2nd	2·67	......	21·36
Pure bone-ash yielded to distilled water 1·20 grs. of phosphate per gallon		·39	of phosphates of lime and magnesia	3·12
Commercial bone-ash yielded to distilled water 1·76 of phosphate per gallon	1st	·40	of bone-ash	3·20
	2nd	·37	,,	2·96
Coarse hard bone-dust yielded to distilled water, after 3 days, ·48 of bone-earth; after 12 days, ·80	1st	·12	after 3 days	·96
	2nd	·47	after 12 days	3·76
Cambridgeshire coprolites yielded to distilled water ·56 grs. of phosphate per gallon	1st	·20	......	1·60
	2nd	·18	......	1·44
Suffolk coprolites yielded to distilled water ·56 grs. of phosphate per gallon	1st	·15	......	1·20
	2nd	·13	......	1·04

In all these experiments the solubility of phosphate of lime has been considerably increased by the presence of sal ammoniac in the water with which the phosphatic materials have been brought into contact.

In the case of precipitated phosphate of lime, the difference in the solubility in distilled water and water containing sal ammoniac is very great indeed. In mineral analyses in which phosphate of lime has to be determined, the filtrate from the phosphates contains usually sal ammoniac, and in this solution phosphate of lime, it has been shown, is soluble to a considerable extent; it is therefore desirable to remove from this solution the lime by oxalate of ammonia, then to evaporate to dryness, and to drive off the ammoniacal salts by heat. In the residue the small but appreciable quantity which ought by no means to be neglected in accurate analysis will be found, and may be determined by $2NaO, PO_5$ and ammonia.

Solubility of phosphate of lime in solutions containing 1 per cent. of carbonate of ammonia.

Carbonate of ammonia, like sal ammoniac, appears likewise to render phosphate of lime more readily soluble than it is in pure water. This will be seen by the following results:—

	Amount of phosphate dissolved in 1 pint. Exp.	grs.	Calculated per gallon. grs.
Precipitated phosphate of lime	1st	1·42	11·36
	2nd	1·40	11·20
Suffolk coprolites	1st	·21	1·68
	2nd	·22	1·76
Cambridgeshire coprolites	1st	·19	1·52
	2nd	·21	1·68

Solubility of phosphate of lime in water containing 1 per cent. of common salt.

I have now to mention experiments which have shown me that neither chloride of sodium nor nitrate of soda has increased in any marked manner the solubility of phosphate of lime in the materials used in my experiments.

The results obtained with solutions containing 1 per cent. of chloride of sodium are embodied in the following table:—

Amount of phosphates dissolved by water containing 1 per cent. of chloride of sodium in solution.

	In 1 pint. Exp.	grs.	Calculated per gallon. grs.
Precipitated phosphate of lime	1st	·52	4·16
	2nd	·55	4·40
	3rd	·58	4·64
	4th	·57	4·56
Pure bone-ash yielded 1·20 grs. of bone-earth to water per gallon		·12	·96
Commercial bone-ash yielded 1·76 grs. of bone-earth to water per gallon	1st	·16	1·28
	2nd	·18	1·44
Cambridgeshire coprolites	1st	·10	·80
	2nd	·12	·96
Suffolk coprolites	1st	·10	·80
	2nd	·12	·96

It might appear that in the first four experiments the presence of common salt had reduced the solubility of precipitated phosphate of lime; but I do not think this was the case in reality, for the difference in the results obtained with distilled water and water containing 1 per cent. of salt is due to the fact that in evaporating the solution of phosphate of lime a considerable quantity of common salt is left, the removal of which necessitates the use of distilled water. The washings necessarily contain a little phosphate of lime; hence the apparent diminished solubility of phosphate of lime in solutions containing 1 per cent. of salt.

Solubility of phosphate of lime in solutions containing 1 per cent. of nitrate of soda.

The following results were obtained in precisely the same way as in the experiments with chloride of sodium:—

	Exp.	Amount of phosphate of lime dissolved by 1 pint. grs.	Calculated per gallon. grs.
Precipitated phosphate of lime in moist condition	1st	·87	6·96
	2nd	·85	6·80
Commercial bone-ash	1st	·18	1·44
	2nd	·20	1·60
Suffolk coprolites	1st	·13	1·04
	2nd	·10	·80
Cambridgeshire coprolites	1st	·12	·96
	2nd	·15	1·20

It appears from these experiments that nitrate of soda has no influence on the solubility of phosphate of lime; for the differences in the amount of phosphate of lime obtained from solutions containing 1 per cent. of nitrate of soda, and from distilled water left in contact with phosphate of lime, are too small to be due to any other cause than to the necessary errors which attach to all analytical determinations of this kind.

Provisional Report on the Present State of our Knowledge respecting the Transmission of Sound-signals during Fogs at Sea. By HENRY HENNESSY, *F.R.S., Professor of Natural Philosophy in the Catholic University of Ireland.*

IN accordance with a request from the President and Committee of Section A, I have drawn up the following provisional report on the state of our knowledge relative to sound-signals during fogs at sea.

It is unnecessary to enter into any details as to the methods in actual use for signalling vessels during fogs. These methods are admittedly imperfect; they have been devised with little regard to scientific principles, and they do not fulfil the purposes for which they are intended*. The objects to be attained by sound-signals during fogs are twofold: first, to reveal the presence of ships to each other, or of light-houses and beacons to ships; secondly, to

* Admiral FitzRoy furnishes an illustration, by an extract from a letter of the late Captain Boyd, relative to a dense fog which prevailed in a part of the Irish Channel on the day before the 'Royal Charter' storm. Only a few explosions from guns fired with full charges from the seaward side of the flagship at Kingstown were heard on board the Holyhead packet, when the distance of the latter did not exceed one mile. The fog-bell was heard when the packet was about half a mile distant, but only when the fog had lifted. We may conclude, therefore, that as long as this fog rested on the water the bell was useless, and the heavy firing was only partially useful. See "Storms of the British Isles. Tenth number of Meteorological Papers, published by authority of the Board of Trade," p. 44.

reveal the relative directions in which such objects may happen to lie. On both of these points some information has been collected by the recent Commission of Light-houses and Beacons. The amount of this information is, however, remarkably meagre when contrasted with the elaborate details furnished by the portion of the report relative to optical signals. This circumstance is freely admitted; and at p. xviii of the Report the desirableness of further experiments on the question of sound-signals is distinctly declared.

But as the Commissioners received suggestions from several men of science who had paid attention to the phenomena of sound, a condensed sketch of such suggestions will be found to present much of the knowledge we possess upon this question. Before presenting a brief summary of these views, it is right to point out that the earliest experiments which have any important bearing upon the subject were instituted many years ago by M. Colladon, on the Lake of Geneva. I refer to his well-known researches on the propagation of sound in water. The manner in which the acoustical properties of air are diminished by fogs has recently induced men of science (including many of those who communicated their views to the Commissioners of Light-houses) to recommend the employment of water as a medium for the transmission of sound. Almost all we know upon this matter is due to M. Colladon*. At first he found that subaqueous sounds were totally reflected at the surface, at such angles as rendered it impossible to hear them above water for distances exceeding 200 metres. To remove this obstacle to his researches he contrived a very ingenious apparatus, that we may for brevity call a hydrophone. Its shape resembled that of a common tobacco-pipe, with a broad and very shallow bowl. Its total length was about 5 metres, or a little more than 16 feet. The pipe was about 18 inches in diameter, tapering at the end close to the ear, where it terminated in an orifice of about 8 inches. The mouth of the bowl was closed by a partition, whose surface amounted to a little more than 2 square feet (20 square decimetres). The hydrophone was entirely made of thin sheets of tinned iron. With this apparatus M. Colladon could hear a bell under water at a distance of 14,000 metres as well as he could by simply plunging the head at a distance of 200 metres. Subsequent to his earlier experiments, M. Colladon succeeded in transmitting distinctly audible sounds under water to the distance of 35,000 metres. The noise of the waves and wind produced little or no effect in diminishing the subaqueous sound, which could be clearly distinguished even when the observer's boat had to be held by several anchors in tempestuous weather. The intensity of the sound was so little weakened by distance, that M. Colladon concludes that the decrease is as the simple distance, and not as the square of the distance, as in the air. This is explained by considering that the propagation of sound takes place in a sheet of water, limited between two surfaces, from which vibrations are totally reflected at acute angles. On these grounds, as well as from his experiments, he foresees the possibility of transmitting sounds at sea to distances of some hundreds of thousands of metres, and of applying such sounds to purposes connected with navigation, such as occupy us in the present inquiry. One of his most remarkable results is that of the existence of an acoustic shadow under water. This was proved by the effect of an interposed wall, in experiments made along the shore of the lake. This result is especially important in assisting in determining the direction of a given sound by the interposition of screens, and on this point water seems to possess decided advantages over air.

* Mém. de l'Inst. Savants Etrangers, v. p. 320. Letter to M. Arago, Annales de Chimie et de Physique, p. 525, vol. ii. 3e série.

The suggestions of scientific men to the Commissioners of Light-houses refer principally to sounds propagated in air. Dr. Robinson points out that the sound should be as discordant as possible with that of the wind and waves, which are said to belong to C. He thinks that sound should be produced as near the sea-level as possible. Mr. Mallet calls attention to explosive sounds as assisting the ear in ascertaining direction. Admiral FitzRoy suggests sharp high-pitched notes, with trumpet-mouthed devices for ascertaining the direction. He thinks that the source of sound should be at a low level. Sir John Herschel recommends the trial of a battery of steam-whistles blown by high-pressure steam; by a combination of three or several sets of three whistles pitched exactly to harmonic intervals (key note third, fifth, and octave), and with a rattle which intensifies the action on the auditory nerve. He also suggests concave reflectors, and the subaqueous propagation of sound by explosions in the foci of large and heavy parabolic reflectors. Professor Potter suggests the use of ear-trumpets, in order to assist observers. Professor Rankine recommends a parabolic ear-trumpet for the determination of direction. The Abbé Moigno maintains that a continuous grave sound spreads further than a very acute violent sound. Thus he instances the greater distance at which the sound of a cannon can be heard compared to thunder. He suggests resonant tubes like those attached to Savart's acoustical apparatus. He thinks such resonant tubes far more effective than reflectors. He also recommends, for ascertaining direction, the use of a differential ear-trumpet, like Dr. Scott Alison's stethophone*. He thinks that sound should be produced close to, or even in the water, and that a series of defined sounds could be arranged beforehand, one being assigned to each maritime station. He refers to M. Colladon's experiments for details relative to subaqueous sounds. Mr. J. Mackintosh, of Liverpool, makes a suggestion in complete accordance with M. Colladon's conclusions. He suggests a deep well in light-ships, whence the sound of a large bell might be propagated all around through the water. A kind of hydrophone applied from a vessel to the water might enable an observer to find the position of the light-ship. These suggestions contain nearly all the information presented in the Report on Light-houses and Beacons. Remarks made by other gentlemen are either equivalent to some of the foregoing, or have reference only to some improvements in the details of the existing system of fog-bells.

Professor Wheatstone has informed me that it had been his intention, in co-operation with the late Mr. Robert Stephenson, to institute a series of experiments on sound, with reference to fog-signals. For this purpose Mr. Stephenson intended to employ his own yacht; and had he been spared longer to science, the information we possess would probably have been less meagre than it is. Professor Wheatstone thinks that a battery of shrill whistles very nearly, but not entirely in unison would be most effective in forcing sound through a fog. Liquid and solid conductors should be as much as possible availed of during fogs. Water would be a far better conducting medium than air for assisting in the determination of direction.

If we are entitled to come to any positive decision upon the evidence which we possess, I should say that water seems to present in a higher degree than air during fogs, the qualities required in a sound conductor. High-pitched sounds seem to be generally acknowledged as most penetrating during fogs, but we have little information as to the detection of the direction of such sounds. On the other hand, we already possess a clue to the direction of subaqueous sounds in M. Colladon's acoustic shadow. Upon the

* Proceedings of the Royal Society, and Phil. Mag. May 1858.

whole, I have been led to the conviction that further experiments are required, which, if properly devised, will not only lead to some important practical results, but perhaps throw light on obscure portions of the theory of sound. I may be permitted to suggest, therefore, that experiments should be made, 1st, on the best kind of sound for penetrating fogs; 2nd, on the adaptation of the principle of interferences for determining directions; 3rd, on the best mode of utilizing the sound-conducting properties of water, by the use of screens and hydrophones; 4th, on the best construction of double ear-trumpets for assisting observers in deciding upon the direction of a given sound; 5th, on the influence of winds in modifying the intensity and apparent direction of sounds.

Report on the Present State of our Knowledge of the Birds of the Genus Apteryx *living in New Zealand. By* Philip Lutley Sclater *and* Ferdinand von Hochstetter.

There appears to be sufficient evidence of the present existence of at least four species of birds of the genus *Apteryx* in New Zealand, concerning which we beg to offer the following remarks, taking the species one after the other, in the order that they have become successively known to science.

1. Apteryx australis.

Apteryx australis, Shaw, Nat. Misc. xxiv. pls. 1057, 1058, and Gen. Zool. xiii. p. 71; Bartlett, Proc. Zool. Soc. 1850, p. 275; Yarrell, Trans. Zool. Soc. i. p. 71. pl. 10.

The *Apteryx australis* was originally made known to science by Dr. Shaw about the year 1813, from an example obtained in New Zealand by Capt. Barclay, of the ship 'Providence.' This bird, which was deposited in the collection of the late Lord Derby, was afterwards described at greater length in 1833 in the 'Transactions of the Zoological Society' by Mr. Yarrell, and was still at that date the only specimen of this singular form known to exist. Examples of *Apteryx* subsequently obtained, though generally referred to the present species, have mostly belonged to the closely allied *Apteryx mantelli* of Bartlett, as we shall presently show, though specimens of the true *Apteryx australis* exist in the British Museum and several other collections.

The original bird described by Dr. Shaw is stated by Mr. Bartlett (Proc. Zool. Soc. 1850, p. 276) to have come from Dusky Bay in the province of Otago, Middle Island, where Dr. Mantell's specimen, upon which Mr. Bartlett grounded his observations as to the distinctness of this species and *Apteryx mantelli*, was also procured.

Dr. Hochstetter was able to learn nothing of the existence of this *Apteryx* in the province of Nelson in the same island; and the species is so closely allied to the *Apteryx mantelli*, as to render it very desirable that further examples of it should be obtained, and a rigid comparison instituted between the two. At present, however, we must regard this form of *Apteryx* as belonging to the southern portion of the Middle Island.

2. Apteryx owenii.

Apteryx owenii, Gould, Proc. Zool. Soc. 1847, p. 94; Birds of Australia, vi. pl. 3.

Owen's *Apteryx*, which is readily distinguished from the preceding species and *A. mantelli* by its smaller size, transversely barred plumage and slender bill, was first described by Mr. Gould in 1847, from an example procured by Mr. F. Strange, and "believed to have been obtained from the South Island." Since that period other specimens have been received in this country, which have sufficed to establish the species; and from the information obtained by Dr. v. Hochstetter, there is no doubt of this being the common *Apteryx* of the northern portion of the Middle Island.

"In the spurs of the Southern Alps, on Cook's Straits, in the province of Nelson," says Dr. v. Hochstetter, "that is, in the higher wooded mountain-valleys of the Wairau chain, as also westwards of Blind Bay, in the wooded mountains between the Motucka and Aorere valleys, Kiwis of this species are still found in great numbers. During my stay in the province of Nelson I had myself two living examples (male and female) of this species. They were procured by some natives, whom I sent out for this purpose, in the upper wooded valleys of the River 'State,' a confluent of the Aorere, in a country elevated from 2000 to 3000 feet above the sea-level. It appears that this *Apteryx* still lives very numerously and widely spread in the extended southern continuations of the Alps."

3. Apteryx mantelli.

Apteryx australis, Gould, Birds of Australia, vi. pl. 2.
—— *mantelli*, Bartlett, Proc. Zool. Soc. 1847, p. 93.

The characters which distinguish this commoner and better-known *Apteryx* from the true *A. australis* of Shaw were pointed out by Mr. Bartlett at the meeting of the Zoological Society held on the 10th of December, 1850. "This bird differs from the original *Apteryx australis* of Dr. Shaw," says Mr. Bartlett, "in its smaller size; its darker and more rufous colour; its longer tarsus, which is scutellated in front; its shorter toes and claws, which are horn-coloured; its smaller wings, which have much stronger and thicker quills; and also in having long straggling hairs on the face."

Mr. Bartlett tells us that, as far as he has been able to ascertain, all specimens of *Apteryx mantelli* are from the Northern Island; and this is completely confirmed by Dr. von Hochstetter's observations, which are as follows:—

"In the northern districts of the Northern Island this species of *Apteryx* appears to have become quite extinct. But in the island called Hou-tourou, or Little Barrier Island (a small island, completely wooded, ranging about 1000 feet above the sea-level, and only accessible when the sea is quite calm), which is situated in the Gulf of Hauraki, near Auckland, it is said to be still tolerably common. In the inhabited portions of the southern districts of the Northern Island also, it is become nearly exterminated by men, dogs and wild cats, and here is only to be found in the more inaccessible and less populous mountain-chains—that is, in the wooded mountains between Cape Palliser and East Cape.

"But the inhabitants of the Northern Island speak also of two sorts of *Kiwi*, which they distinguish as *Kiwi-nui* (Large Kiwi) and *Kiwi-iti* (Small Kiwi). The Kiwi-nui is said to be found in the Tuhna district, west of Lake Taupo, and is, in my opinion, *Apteryx mantelli*. The Kiwi-iti may possibly be *Apteryx owenii*, though I can give no certain information on this subject."

4. Apteryx maxima.

"The Fireman," Gould in Birds of Australia, sub tab. 3. vol. vi.
Apteryx maxima, Bp.

"Roa-roa" of the natives of the Southern Island.

The existence of a larger species of *Apteryx* in the Middle Island of New Zealand has long ago been affirmed, and though no specimens of this bird have yet reached Europe, the following remarks of Dr. v. Hochstetter seem to leave no reasonable doubt of its actual existence:—

"Besides *Apteryx owenii*, a second larger species lives on the Middle Island, of which, although no examples have yet reached Europe, the existence is nevertheless quite certain. The natives distinguish this species not as a *Kiwi*, but as a *Roa*, because it is larger than *A. owenii* (*Roa* meaning 'long' or 'tall').

"John Rochfort, Provincial Surveyor in Nelson, who returned from an expedition to the western coast of the province while I was staying at Nelson in his Report, which appeared in the 'Nelson Examiner' of August 24th, 1859, describes this species, which is said to be by no means uncommon in the Paparoa chain (a wooded range of about 2000 to 3000 feet in elevation between the Grey and Buller Rivers), in the following terms:—'A Kiwi about the size of a Turkey, very powerful, having spurs on his feet, which, when attacked by a dog, defends himself so well as frequently to come off victorious.'

"My friend Julius Haart, a German, who was my travelling companion in New Zealand, and in the beginning of the year 1860 undertook an exploring expedition to the southern and western parts of the province of Nelson, writes to me in a letter dated July 1860, ten miles above the mouth of the river Buller, on the mountains of the Buller chain (which, at a height of from 3000 to 4000 feet, were at that time—it being winter in New Zealand—slightly covered with snow), that the tracks of a large Kiwi of the size of a Turkey were very common in the snow, and that at night he had often heard the singular cry of this bird, but that, as he had no dog with him, he had not succeeded in getting an example of it. He had, nevertheless, left with some natives in that district a tin can with spirits, and promised them a good reward if they would get him one of these birds in spirits and send it to Nelson by one of the vessels which go from time to time to the west coast."

In concluding this brief Report, we wish to call attention to the importance of obtaining further knowledge respecting the recent species of this singular form of birds whilst it is yet possible to do so. We see that one of them (the *Apteryx mantelli*) is already fast disappearing, whilst its history, habits, mode of nidification, and many other particulars respecting it are as yet altogether unknown. We therefore trust that such members of this Association as have friends or correspondents in any part of New Zealand will impress upon them the benefits that they will confer on science by endeavouring to procure more specimens of, and additional information concerning, the different species of the genus *Apteryx*.

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. By J. Gwyn Jeffreys, *F.R.S., F.G.S.*

The Report was submitted by the author, as one of the General Dredging Committee, not so much for the sake of announcing his discovery of new species, as of maintaining certain views which he had ventured to suggest on former occasions with respect to the geographical distribution of the marine fauna of Europe. A yachting excursion which he had taken in the course of this summer, accompanied by two scientific friends, to the northernmost part of the British Isles, together with an examination of the upper tertiaries in Suffolk and Norfolk which he had since made in company with Mr. Prestwich, gave the author a better insight into the scope of such distribution than had resulted from his previous researches, and confirmed his belief that the division into separate areas or "provinces," which had been proposed by so many systematists (all of whom held different opinions as to the extent and limits of such "provinces"), was erroneous, and that the present distribution must be referred to a state of things which has indeed passed away, but left a very distinct impress of its action. The author is inclined to take the Coralline Crag as a starting-point, and to consider the marine fauna of Europe, Northern Asia, the Cis-Atlantic zone of Africa, and part of North America, as having been closely related at a comparatively recent epoch, and as forming one common area of origin. Many species of Mollusca once existed at both extremities of this vast district—*e.g. Mya truncata* and *Buccinum undatum*; and other species hitherto supposed to be restricted to the Mediterranean (viz. *Monodonta limbata* and *Cerithium vulgatum*, with its variety *C. calabrum*) have lately been discovered by Professor Sars on the coasts of Finmark. It is also probable that the recent exploration of the Greenland seas by Otto Torell and others may reveal further instances of a similar kind. Very little has hitherto been done towards the investigation of the Arctic fauna. It by no means follows that an extremely rigorous or "arctic" temperature prevailed in those places where we find the remains of some Mollusca which now inhabit only the seas of colder regions, or, *vice versâ*, that the presence in these regions of fossil shells belonging to species which now inhabit only more southern seas indicates the former prevalence of a warm climate. The temperature of the sea at certain depths is well known to be very equable; and it is only littoral or shallow-water species that would be exterminated or affected by a change of climate. Some kinds appear to be more hardy than others, and to have survived considerable and perhaps frequent changes of temperature; while others have undergone a limited modification of form, and are considered by some naturalists as distinct (or "representative") species. A great deal, however, yet remains to be done, by accumulating facts, and a critical comparison of recent with fossil species, before a complete or satisfactory theory of distribution can be established.

Mr. Jeffreys contrasted his experience of this dredging expedition with those he had made to other parts of the British coasts as well as to the Mediterranean, and also with the accounts he had received of similar expeditions to the coasts of Norway and Sweden—showing the far greater difficulties which attended an exploration of our northernmost sea, by reason of the variable and often tempestuous weather, and of that line of coast being unsheltered from the prevailing winds. He, however, succeeded in procuring three species of Mollusca new to science, which he proposed to name *Margarita elegantula, Aclis Walleri*, and *Nassa? Haliaëti*, besides twelve other species which were new to the British Isles. Of these last, ten are Scandinavian, one is Mediterranean, and the other had hitherto been known only as a Crag fossil. He reserved the description and particulars of these species for a work on British Conchology which he had undertaken. He ascertained that the Gulf-stream never impinges on any part of the coast which he had examined, although the climate was temperate.

The author noticed the occurrence at considerable depths (nearly 80 fathoms) of living Mollusca which usually inhabit the shore or very shallow water, viz. *Lamellaria perspicua*, *Nassa incrassata*, and *Cypræa Europæa*, all of them being widely diffused species,—thus apparently illustrating the view entertained by the late Professor Edward Forbes, that those species which have the widest horizontal range have the greatest vertical depth. Judging, however, from the great depth at which he found the fossil shells of some Mollusca (*e.g. Pecten Islandicus* and *Mya truncata* var. *Uddevallensis*) which inhabit much shallower water in the Arctic zone, the author is disposed to believe that the bed of this part of our Northern Sea has sunk since the so-called "glacial" epoch, and that this circumstance may possibly account for the above-mentioned occurrence of sublittoral species at such depths.

With respect to the comparative size of those Mollusca which are common to the seas of the North as well as of the South of Europe, the author referred to an observation made by Mr. Salter, in a recent number of the 'Quarterly Journal of the Geological Society,' that some fossil shells which Mr. Lamont had brought from Spitzbergen were larger than those of the corresponding species in our own mountain limestone; and he remarked that the same rule appears to apply also to marine plants, for he never saw such gigantic fronds of the *Laminaria saccharina*, which fringes all our coastline, as he did in the voes of North Zetland.

The author concluded by paying a just tribute of respect to the labours of Professors Sars and Lovén, Malm, Mörch, Asbjörnsen, and other Scandinavian naturalists, who were investigating the Mollusca of the Northern seas with a zeal and accuracy worthy of our emulation.

Contributions to a Report on the Physical Aspect of the Moon. By J. Phillips, *M.A., LL.D., F.R.S., Professor of Geology, Oxford.*

Professor Phillips noticed the result of his sketches of parts of the surface of the moon, and also described Mr. Birt's contributions to a report on selenography, which had been undertaken by direction of the General Committee at Oxford, with the view of discovering the character of the moon's surface as influenced by previous physical events. Professor Phillips's observations related especially to the mountain Gassendi, to which his attention had been directed by the Committee in 1852, but included also drawings of remarkable 'rills,' and other interesting peculiarities, in Aristarchus, Archimedes, and Plato.

The rills to which Prof. Phillips had given principal attention were—(1) the well-known stag's-horn rill E. of Thebit, which appeared to be what geologists call a 'fault' or 'slip,' one side elevated above the other, and with some inequality in the dislocation when the shadow is accurately inspected; (2) the long rill on which the small crater called Hyginus is situated; (3) the group of parallel rills about Campanus and Hippalus. Regarding these it was remarked that the drawing of Mädler, which, like all the work in his great map, was obviously a careful one, differed in one point from that made by Prof. Phillips. This difference may be thus stated. In Mädler's drawing three parallel rills appear in the space between Campanus and Hippalus; the middle one, shorter than the others, passes between two small hills. Prof. Phillips draws these two hills near to each other, and records no rill running between them. The rill between these hills and Hippalus appears in both drawings; but Prof. Phillips continues it further to the south, even *into* the crater marked A, which is likewise *traversed* by the longest rill of all, that, viz., nearest to Campanus. Another rill is traced by Prof. Phillips quite across and through the old crater of Hippalus; and all the rills appear to him to be *rifts* or deep fissures, receiving strong shadows from oblique light, and even acquiring brightness on one edge of the cavity. Their breadth appears to be only a few hundred feet or yards. He exhibited drawings of these objects on a large scale, one being a section across the crater of Gassendi, another a map of the curious region extending from Aristarchus and Herodotus along the interrupted rift or valley which opens by a seeming delta into the seeming dried sea-bed with indented coasts on the south.

Speaking of Gassendi, of which he had made drawings under different conditions of light and shade, from sunrise on the mountains to mid-day, and slighter sketches at later hours, he remarked, in addition to what has been recorded by Mädler, the much-varied character of the 'rings,' the deep narrow fissures across the ring on the S.E. side, the rocky character of the central elevations in the interior area, the rough terraces and ridges within the great ring on the east and also the north-west side, the occurrence of only two small craters in the northern part of the area, and the variation of colour on the surface, without shadow, according to the change of the angle of incidence of the sun's rays.

He also drew attention to the existence of delicate ramifications of small ridges and hollows in the S.W. part of the area, which had a marked convergence towards the broad lip of the deep-attached cavity known as the Spoon. He expressed his great desire to receive drawings of Gassendi as seen at noon and at later hours of the lunar day.

Contribution to a Report on the Physical Aspect of the Moon. *By* W. R. Birt, *F.R.A.S.*

On the present occasion I propose confining my contribution to the physical features characterizing the well-known spot Plato, some of which are familiar to astronomers, while others, I have some reason to believe, have not hitherto been pointed out. I have included all that have come under observation during the twenty-nine months between January 1860 and May 1862, inclusive, in a synopsis of objects suitable for further telescopic observation. This synopsis of objects is necessarily *incomplete*. To each object observed I have appended, *in italics*, the number of times it has been the subject of special observation; so that every one inserted in the key-plan has been seen by me at some time during the interval of the observations above mentioned. The entire period of the visibility of Plato is embraced in the observations, which are, however, more numerous under the morning and mid-day illuminations than under the evening. Those features that have been more frequently observed may of course be regarded as being more fully established, at least for the period embraced by the observations; the synopsis forming a groundwork for the more effectual observation of Plato, especially as regards the interesting questions of absolute repose now existing on the moon's surface, or the progress of change such as may be detected by human eyes. Forty-five series of observations contributing to the synopsis, and extending from January 5, 1860, to July 29, 1861, I have arranged in the order of the moon's age, in a MS. volume which is deposited in the library of the Royal

Astronomical Society. The remainder, twenty-three, bringing the observations to May 12, 1862, are at present in my hands, and are intended to form part of a second volume, should I be able to pursue the observations. The arrangement of the volume is such that it can be used as an ephemeris of the successive appearances of the crater, as well as being indicative of those objects that require careful and steady watching.

One of the most interesting objects among those newly pointed out is a terrace on the south-west interior slope. It, with a ravine in the same neighbourhood, is of an exceedingly delicate character, being brought out (especially the terrace) by the gradual change in the direction of the incident solar ray.

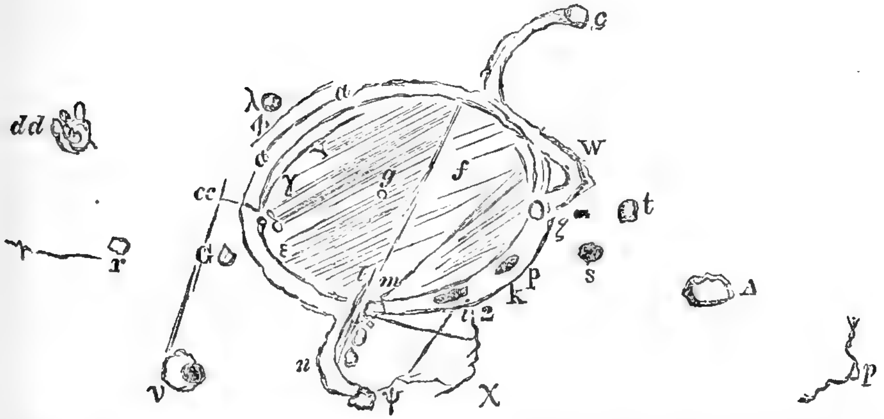
Accompanying the synopsis are two illustrative figures. Fig. 1 is a somewhat rough *key-plan* of the crater, the ellipse being that of the greatest opening presented by Plato. This key-plan possesses no pretensions either to accuracy of detail or correctness of locality, *micrometrically considered*; it is only offered as a guide to the general and relative positions of the objects included in the synopsis. Fig. 2 is a section indicated by observation of the south-west interior slope of Plato, showing the terrace or ledge Y, one of the new features brought to light by this series of observations. The reader is referred to Beer and Mädler's large map of the moon, and is specially requested to compare the delineation of the crater as they have given it with the key-plan accompanying this Report. A careful comparison of them will show the features they have in common, and the departures that may exist in those determined by the present series of observations from the representations of the same features as given by Beer and Mädler. Schröter has given some of the features mentioned, especially the mountain-range (n), which he marks μ, the mountain ν, the shadows of the three peaks γ, δ, and ϵ, the mountain c, which in Schröter's drawing is marked D, and the crater χ, which is no longer in existence—if Schröter really saw a perfect crater as he has delineated it. In another delineation of Plato by Schröter, showing the two markings i and k on the interior of the north-east slope as he observed them on December 11, 1788, he also gives a remarkably round cloud-like appearance, not unlike in character to the one that has been so constantly a subject of my own observation, marked f in the key-plan. These delineations may be found in his 'Selenotopographische Fragmente,' t. xxi.

To render the results of the inquiry of greater value, a careful micrometrical survey of Plato, when presented under the greatest visual angle, would be important. Every well-determined spot would be laid down in its accurate position as seen from the earth under that angle; and if such a survey were executed with the requisite precision, one epoch only being fixed on, and no reduction to a mean state of libration admitted, it would not be difficult, after a few years' observations, to judge of the probable fixity of aspect presented by the most prominent features, and changes, if any, would soon render themselves apparent.

Synopsis of objects in Plato suitable for telescopic observation, with reference to fixity or variability of absolute aspect.

By absolute aspect, I mean the aspect dependent on the object itself, its form and constitution,—not an aspect dependent on the variability of the incidence of solar light, or on the variability of the direction of the visual ray as the object is seen from the earth, the one indicated by the moon's age, the other by the libration of the moon.

Fig. 1.



Key-plan of Plato, from observations by W. R. Birt, F.R.A.S., between January 5, 1860, and October 19, 1861.

I. *n*.—A short range of mountains running at first nearly at right angles to the mountainous rim of Plato, from a break in the northern or, rather, north-western portion of the rim. This range of mountains is of a curved form, and terminates in the mountain ψ. It constitutes the western rim of a crateriform formation to the north of Plato.

This mountain-range has been the subject of *eleven* observations between January 1860 and May 1862. Schröter had previously observed it, and marked it μ. Under a suitable illumination, a shallow depression is seen westward of this mountain-range, the land rising a little on the westward of it, so that a somewhat narrow valley is enclosed between the two. There are two well-defined peaks on the eastern or highest range, and a small one between them and the rim.

II. *l*.—A break on the north-western rim of Plato, which is doubtless the continuation of the narrow valley west of the mountain-range (*n*). It is distant about 0·75 of the longest diameter of the apparent ellipse from the east, and is very distinctly shown in the drawing of Schröter.

The observations of this break in the rim of Plato have been numerous. On *three* occasions the valley-like character of it has been recorded. Under a suitable illumination, a bright streak from Anaxagoras to Plato may be seen terminating near this break.

III. *m*.—A bright spot on the north-west portion of the rim, close to and east of the valley (*l*). On the 28th of May, 1860, I have recorded a high alpine mountain in the locality of this spot.

This bright spot has been observed on *nine* occasions, and on one occasion as a dusky spot.

IV.—The interior slope of the north and north-east border. This slope undergoes variations of luminosity, according as the incidence of the solar rays vary; it has two dark oval markings.

V. 2.—Under a somewhat late illumination, 21·5 days moon's age, the rim of this part of Plato presents the appearance of a sharp angle in the neighbourhood of the westernmost of the two oval markings, and from this point an irregularly formed crag overhangs the slope. This crag has also been seen under the morning illumination.

There are strong indications of a circular range of mountains existing on the north of Plato, of which the range (*n*) forms the western side: the included area is crossed by two dark but narrow lines, which appear to be of the nature of fissures. They, with the circular range, have only been observed *once*. (See key-plan, fig. 1.)

VI. *i*.—The westernmost of the two oval markings.

VII. *k*.—The easternmost of the two oval markings.

Schröter appears to have observed them on December 11, 1788: he has figured them on t. xxi. fig. 6. They have been observed by the writer on *fifteen* or *sixteen* occasions at least.

VIII. *p*.—A bay-like indentation in the north-east rim seen under the mid-day illumination. It has been observed on *five* occasions. It is not shown in the key-plan, but its locality is indicated by the letter *p*.

This indentation, which is best seen about full moon, or about fifteen or sixteen days of the moon's age, marks, I apprehend, the form of the rim of Plato hereabout. It is well shown in a sketch by Webb, under date of 1855, October 24, ten to eleven hours; the sketch is preserved in the volume of Observations on Plato deposited in the library of the Royal Astronomical Society. It is approximately figured at *p*, detached from the key-plan of the crater, as it is only visible for about two days near the full.

IX. *q*.—A short, light spur in the neighbourhood of *p*, which, with the shadow within the cavity *i*, appears to indicate the existence of a ledge or terrace in this part of Plato. It has only been observed *once*.

X. *ζ*.—A bold rock jutting into the interior, casting a well-defined shadow eastward in the morning and forenoon, and westward on the floor of the crater towards sunset: it is more frequently observed as the eastern extremity of the longest diameter of the apparent ellipse.

This rock is one of the finest and most conspicuous objects in the neighbourhood of Plato during the morning illumination, glowing in the rays of the sun like molten silver. From about 7·5 to 8·5 days of the moon's age, it is seen as a very brilliant point at the eastern extremity of the crater; during the next two days (from 8·5 to 10·5 days of the moon's age) it is very distinguishable, standing out as a bold rock, and casting a well-defined shadow eastward; during the next three days (from 10·5 to 13·5) it loses its shadow, but continues a perceptibly bright object, imparting to the eastern extremity its peculiar brilliancy at this age of the moon. It is now lost for some time. About nineteen days of the moon's age it has been seen very distinctly; two days later, viz. at twenty-one days, its shadow has been seen on the floor of Plato; and about this time, or rather later, it has been seen standing out in fine and bold relief, a magnificent object, its height above the general altitude of the ring being apparent not only by the acuminated character of its shadow on the floor of the crater, but by its towering considerably above the general summit. It appears to be a formation in a measure distinct from the ring itself, and greatly allied in its character to that of Pico on the south of Plato; indeed, it deserves as conspicuous a position on a map as Pico. It possesses two bold spurs on the north-east and south-east. Its very appearance is exceedingly suggestive, especially when taken in connexion with a formation immediately south of it. Both should be most carefully and scrupulously watched, in order to determine if any degrading forces are at work hereabout.

This rock has been observed under the morning and forenoon illuminations on *eighteen* occasions, and under the evening on *four* occasions. Schröter gives a rude figure of it in t. xxiii.

XI. *s*.—A spot situated on the eastern exterior slope of Plato: it is slightly to the north of eastward of the rock *ζ*, and was seen, on October 14, 1861, moon's age 10·55 days, to be a gently rising protuberance on the eastern slope of the rock *ζ*, in the neighbourhood of the north-eastern spur.

XII. *t.*—A small *crater* south of eastward of the rock ζ: it is described, March 22, 9 30 (1861), to be almost due east of the longest diameter of Plato. It is situated on one of the spurs of ζ.

The rock ζ, the spot *s*, and the crater *t*, form a conspicuous triangle, seen to great advantage on March 21, 1861. They have been observed in connexion on *three* occasions.

XIII. A.—The *largest* crater in the neighbourhood of Plato, figured by Schröter, t. xxiii., and marked *c* by him, but A by Beer and Mädler.

XIV. χ.—Schröter also gives another crater of about the same size, which he marks χ, north of Plato. In his delineation it is placed about midway between Plato and the Mare Frigoris. In the whole course of my observations I have not met with this crater, nor have I seen anything similar to that delineated by Schröter. On the night of August 27, 1861, moon's age 21·53 days, I found a very interesting object on the northern boundary of the bright ground north of Plato. It consisted of a semi-elliptical range of mountains very similar to a half-crater, the existing portion of the ring not greatly elevated above the surface; the south-east side was more elevated than the south-west, so that its external slope caught the rays of the afternoon sun, which rendered it the most brilliant object in the immediate locality. The south-west portion of this half-ring was seen to terminate a little short of the line of junction of the bright ground north of Plato and the dark ground of the Mare Frigoris, the south-east portion being cut off sharply by the south edge of the Mare Frigoris. I did not observe any difference of level between the lighter rugged ground on which the half-ring was seen and the darker and smoother surface of the Mare Frigoris. The situation of this half-ring is very near the locality given by Schröter for the perfect crater. I have indicated it on the key-plan by Schröter's mark χ.

I also observed this object on September 13, 1861, under the morning illumination, moon's age 8·87 days; and again on September 25, moon's age 21·08 days. It requires the precise angle of illumination and visual ray to catch it.

XV. W.—An interesting marking just south of the rock ζ, somewhat of the character of a crater, apparently triangular in its form, but on closely scrutinizing it seen to be a somewhat shallow depression having a gently *curved* rampart. Under a suitable illumination, the shadow of this rampart has been seen well defined within the enclosure. The south-east rim of this apparent crater, with the contiguous portion of the rim of Plato, forms the continuation of a chain of mountains which takes its rise at an isolated mountain south-east of Plato (*c*) (see key-plan, fig. 1). This chain of mountains is well seen under the evening illumination about 21·5 days of the moon's age.

The position of this depression is on the upper part of the eastern slope of Plato. It is separated from the large crater by a portion of the eastern rim of Plato, which also forms its western rim. On May 2, 1860, the colour of the interior was very slightly, if any, darker than the surface exterior to Plato, and much lighter than the floor of Plato. It has been observed on *fifteen* occasions.

XVI. *o.*—A small crater at the external common base of the rock ζ and the depression W. It has been observed *twice*.

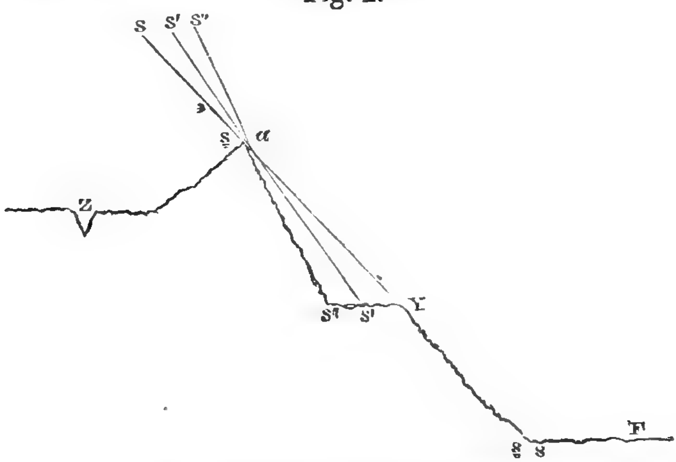
XVII.—The south-east rim of the crater Plato.

XVIII. *c.*—A mountain south-east of Plato. The chain of mountains, of low altitude, running from it in a curved direction to Plato formed part of the ring of the ancient crater called Newton by Schröter. It has been observed at least on *three* occasions.

The existence of this mountain is well established, having been observed by Schröter, and marked by him D; by Beer and Mädler, and marked by them *c*; and by the writer, as above. The chain of mountains is given somewhat differently by each observer, but no doubt can be entertained of its existence.

XIX. Y.—A very narrow ledge or terrace within the interior of the south-west border of Plato, appearing as a lucid fringe when the shadow of the summit of the border is sufficiently narrow to allow of the illumination of the floor of the terrace. See fig. 2, in which

Fig. 2.



Section of the south-west interior slope of Plato, the Hartwell Ledge, from observations by W. R. Birt, F.R.A.S.

F. Represents the floor of the crater.
S—S. The south-west interior slope.
Y. The terrace or ledge.
a. The summit of the slope.
Z. A ravine exterior to the crater.
S—S. The incident ray when the ledge is in deep shadow, the entire floor being illuminated.
S′—S′. The incident ray when the ledge is partly illuminated.
S″—S″. The incident ray when it is wholly so.

On May 18, 7 0, 1861, I observed the interior shadow of the western rim to fine off on the south-west side. It presented the appearance of a very fine line, with *two* bright spots, as if there were two small mountains on the ledge or terrace. With Dr. Lee's permission, I propose to designate this terrace the Hartwell Ledge.

This ledge has been observed on *seven* occasions.

XX. *aa*.—The summit of the south-west slope; observed on *five* occasions.

XXI. Z.—A ravine on the surface exterior to Plato; observed on *thirteen* occasions.

XXII. γ.—A high peak on the south-west wall, recognized in the early morning illumination by its long shadow stretching far along the floor; observed on *six* occasions. Schröter has figured the shadow.

XXIII. δ.—A high peak on the west wall, recognized as above, and figured by Schröter; observed on *two* occasions.

XXIV. ϵ.—A similar peak on the north-west wall, also figured by Schröter, and observed *twice*.

These three peaks occasion at sunrise a well-marked indented shadow, which rather rapidly recedes as the sun becomes elevated above their horizon. Beer and Mädler have indicated, measured, and marked them respectively γ, δ, and ϵ. The shadows have been well seen by the writer on the floor of Plato, with an additional peak.

XXV. *b.*—A dark-black spot in the shadow, most probably the peak δ, which under the early morning illumination would present such an appearance. My observations under the evening illumination have been too few to recognize it as a bright spot, nor have I noticed either γ or ϵ as black spots in the morning shadow. This black spot occupies precisely the position of δ, just north of the termination of the longer axis of the apparent ellipse exactly opposite the rock ζ. It has been observed on *three* occasions.

XXVI. λ.—A conspicuous mountain south-west of Plato, on the ring of Schröter's Newton, and nearly abutting on the ravine Z (XXI.). Beer and Mädler mark it λ, but place it too far to the south-east. It has been observed on *nine* occasions.

Under a very early illumination it may easily be mistaken for a crater (see also XXIX. *r*). There is a gradual rise of the land from the north-west towards the mountain, which itself rises from a depression, the western cliff of which is very abrupt.

XXVII. *dd.*—A group of mountains in the Alps, forming with λ and ν an isosceles triangle, λ and ν being the base. There is a little discrepancy here. The mountain λ has been brought nearer to *dd* on the key-plan than it would be on Beer and Mädler's map, to give it its proper position with regard to Z, *aa*, and Y (see XXVI. λ). It is the author's intention, as early as convenient, carefully to triangulate the most conspicuous objects near Plato.

XXVIII. G.—A small crater, a little to the west of δ, somewhat closely abutting on the summit; it is marked G by Beer and Mädler. I have observed it *twice*. It is very probably the same as ω, in Schröter's drawing.

XXIX. *r*.—A mountain on the exterior western slope of Plato: it is situated in the line of the longer axis of the apparent ellipse. On March 22, 1861, it was seen with the shadow eastward; it had a rounded summit, and the western slope was shining with considerable brilliancy. It has been observed *eight* times. Its situation with regard to *dd* and ν (see key-plan) requires to be determined; also its real character, whether it be a mountain or a crater. On some occasions, under an early illumination, it has been described as a crater; on others, as a mountain. From the description of March 22, 1861, it would appear to be a mountain. It is very conspicuous about the time of full moon as a bright lucid spot.

XXX. *ee.*—A considerable depression east of *r*, and between it and the western rim of Plato. Observed *twice*, under a very early illumination of Plato.

XXXI. *cc.*—A somewhat long dark line, in the nature of a shadow with a short spur, apparently the shadow of a mountain across the western wall of Plato; the long dark line observed only *once*, the spur *twice*. The exact direction of the line requires determination.

XXXII. ν.—A conspicuous mountain north-west of Plato, marked ν by Beer and Mädler; it is figured by Schröter with some smaller mountains and a crater, ϕ, north-west of it. It was well seen on May 18, 1861; also on July 15, 1861, when two well-marked, distinct rocks were seen north-west of it. It has been observed on *seven* occasions.

XXXIII. *ff.*—Three mountain-masses (supposed to be ν and the mountains north-west of it; they are not given in the key-plan) in the neighbourhood of the mountain ν. The westernmost of these mountains not over-bright, but the others very bright.

XXXIV. *gg.*—A crater figured by Schröter, and marked by him ϕ, at the western extremity of the three mountains *ff*. The writer observed and figured it on January 8, 1862; but did not see it on March 8, 1862, when the moon was nearly of the same age.

The floor of Plato presents some exceedingly interesting appearances. It is figured by Beer and Mädler as being crossed by four streaks of a somewhat lighter tint than that of the general surface of the floor (see the large Map). These have not been observed within the epochs limiting the period of the observations forming the basis of this Report, January 1860 and May 1862; but a remarkable, broad, branching, whitish, cloud-like streak, crossing the floor at certain epochs of the moon's age perpendicularly, and at others when it is more distinctly apparent in a diagonal direction (*f*) (see key-plan, fig. 1), has been seen very frequently; in fact, during the continuance of the observations, it may be regarded as having possessed a decided characteristic of *constancy*.

The change of direction of this marking as the sun passes from west to east in his lunar-diurnal course is very interesting, and is in some measure indicative of the nature of the surface of the floor, the direction being apparently dependent on some peculiarity of reflection in the surface. It appears to be connected with the bright mountain (*m*) on the north-west rim, as under certain angles of illumination it is seen invariably to take its rise therefrom. This is a feature that requires careful watching. It has more than once been traced to the rayed crater Anaxagoras, and on a very favourable occasion was seen to be connected with the ray that terminates near the bright mountain *m*. It is only visible during certain epochs of illumination.

Schröter appears to have observed, in December 1788, a somewhat similar marking, but of a round form (consult his figs. 6, 7 and 8, t. xxi.). Taking the three periods of observation, Schröter's, Beer and Mädler's, and the writer's, it would seem that the markings of the floor are of a variable character.

The portion of the floor not covered by this marking, and the whole when it is not visible, undergoes variations of tint, from a decided greenish tint just after sunrise, when it mostly appears with a delicate smooth surface, to a deep-blackish grey, of a diluted inky character, at mid-day, the smoothness of surface having considerably disappeared.

Beer and Mädler have indicated three or four minute specks on the surface; Gruithuisen detected seven. One, nearly central, I have more or less constantly observed under suitable angles of illumination. The Rev. T. W. Webb has also observed this central speck. It is marked *g* on the key-plan.

Preliminary Report on the Dredging Committee for the Mersey and Dee. By Dr. Collingwood *and* Mr. Byerley.

This Committee was appointed last year at Oxford, and the present Report was a *résumé* of all that had previously, and since then, been ascertained concerning the Marine Fauna of that region. The past season having been very unfavourable for dredging operations, several important families still remained unexplored, chiefly among the minuter Crustacea, Annelids, Entomostraca and Foraminifera. The following comparison of ascertained species with those of the British Fauna will serve to show some of the results given.

	Mersey and Dee, &c.	Proportion, about	British.	Characteristic or dominant species.	Rare and remarkable species.
	Species.		Species.		
MARINE FISH	79	$\frac{1}{3}$	216	Lesser Weever, Unctuous Sucker, Armed Bullhead, Sand Lance, Spotted Dog-fish, &c.	Sturgeon, Angler, Lump-sucker, Gemmeous Dragonet, Opah, Angel-fish (*Squatina*), Torpedo, Anglesey Morris, &c.
CEPHALOPODS	6	$\frac{1}{2}$	13	Sepiola atlantica	Octopus vulgaris, Rossia.
GASTEROPODS:—					
Prosobranchiata	31	$\frac{1}{7}$	219	Littorina littorea, Rissoa ulvæ, Purpura lapillus, Buccinum undatum.	Rissoa vitrea, Lacuna crassior, L. vincta.
Opisthobranchiata	5	$\frac{1}{5}$	24	Cylichna obtusa.	Bullæa aperta.
NUDIBRANCHIATA	28	$\frac{2}{7}$	100	Doris bilamellata, D. proxima, Dendronotus arborescens.	Antiopa hyalina, Embletonia pallida, Doris subquadrata, Eolis concinna.
LAMELLIBRANCHIATA	46	$\frac{1}{4}$	166	Mytilus edulis, Cardium edule, Tellina solidula, Mya truncata, Pholas crispata, P. candida.	Montacuta, Artemis, Venus ovata, Crenella marmorata.
TUNICATA	4	$\frac{1}{18}$	73		
CRUSTACEA:—					
Brachyura	10	$\frac{1}{4}$	41	Portunus depurator. Carcinus mænas.	Gonoplax angulata. Corystes Cassivelaunus.
Anomoura	4	$\frac{1}{5}$	20	Pagurus, Porcellana longicornis.	Galathea Andrewsii.
Macroura	7	$\frac{1}{7}$	46	Pandalus annulicornis, Crangon vulgaris.	Pasiphæa sivado.
Amphipoda, Stomapoda, Isopoda	But few.				
ENTOMOSTRACA	9				
ANNELIDA	About 18 genera.		...	Amphitrite ventilabrum.	
ECHINODERMATA	11	...	...	Uraster rubens, Ophiocoma rosula ...	Cucumaria communis.
POLYZOA	21	$\frac{1}{8}$	...	Gemellaria loricata, Alcyonidium gelatinosum.	
HYDROZOA:—					
Corynidæ	7	...	...	Tubularia indivisa.	
Sertulariadæ	19	$\frac{1}{2}$	44	Sertularia pumila, Plumularia falcata	Sertularia Margareta.
Campanulariadæ	7	$\frac{1}{4}$	28	Laomedea gelatinosa.	
Acalephæ	...	...	...	Cydippe pileus, Cyanæa, Aurelia aurita.	Velella spirans.
ACTINOZOA	...	...	...	Tealia crassicornis.	Actinia mesembryanthemum.
SPONGES	Few.	...	...	Halichondria panicea.	

The writer avoided entering upon any general considerations, reserving them for a future and more complete report.

Third Report of the Committee on Steam-ship Performance.

CONTENTS.

REPORT.

AT the meeting of the British Association held at Oxford in June 1860, the Committee was re-appointed in the following terms:—

"That the Committee on Steam-ship Performance be re-appointed, to report proceedings to the next meeting.

"That the attention of the Committee be also directed to the obtaining of information respecting the performance of vessels under sail, with a view to comparing the results of the two powers of wind and steam, in order to their most effective and economical combination.

"That the sum of £150 be placed at the disposal of the Committee."

The following noblemen and gentlemen were nominated to serve on the Committee:—

Vice-Admiral Moorsom.
The Duke of Sutherland (formerly Marquis of Stafford).
The Earl of Caithness.
The Lord Dufferin.
William Fairbairn, F.R.S.
J. Scott Russell, F.R.S.
Admiral Paris, C.B.
The Hon. Capt. Egerton, R.N.
William Smith, C.E.
J. E. McConnell, C.E.
Professor Rankine, LL.D.
J. R. Napier, C.E.
R. Roberts, C.E.
Henry Wright (Honorary Secretary).

With power to add to their number.

The following gentlemen also assisted your Committee as corresponding members:—

Lord C. Paget, M.P., C.B.
Lord Alfred Paget, M.P.
Lord John Hay, M.P.
The Earl of Gifford, M.P.
The Marquis of Hartington, M.P.
Viscount Hill.
The Hon. Leopold Agar Ellis, M.P.
Captain Ryder, R.N.
Captain Hope, R.N.
Captain Mangles.
T. R. Tufnell.
William Froude.
John Elder.
David Rowan.
J. McFarlane Gray.

Your Committee re-elected Admiral Moorsom to be their Chairman, and at his decease the Duke of Sutherland succeeded him.

Your Committee having held monthly meetings, and intermediate meetings of a sub-Committee, presided over by the Chairman, beg leave to present the following Reports:—

At the last meeting of the British Association, after the Committee's Report had been presented, Admiral Moorsom read a paper before the Mechanical Section on the Performance of Steam Vessels, and a discussion ensued which demonstrated the great want that is felt by men of science, both in England and in other countries, of definite knowledge based on actual experiment respecting the resistance offered by vessels of various sizes and types, to being drawn through the water. As the means of trying such experiments could only be satisfactorily obtained from a Government having every description of vessel in its service, your Committee determined urgently to renew their applications to the British Admiralty, that that body should, for the benefit of science generally, conduct a series of experiments; and to state that the Committee were even prepared to advise upon or conduct such experiments, if the Admiralty so desired.

The Chairman accordingly communicated with the First Lord of the Admiralty, repeating the various arguments hitherto advanced, with concise statements of the general nature of the detailed experiments deemed necessary, and which are briefly as follows:—

1. The specific resistance of certain ships selected as types, and of the following displacements, viz.,—about 1000, 2000, 3000, 4000, 5000, 6000, 7000 tons, and upwards. Such resistance under traction being measured by dynamometer, and under the three following conditions:—

(1.) Of the hull when launched.
(2.) Ditto with machinery on board.
(3.) Ditto when ready for sea.

2. The thrust of the screw, measured by dynamometer, when propelled by steam under the two last of the above three conditions, and under similar circumstances of smooth water and calm.

3. Full particulars of the dimensions and form of the ships, of the boilers and furnaces, of the engines, and of the propeller.

4. Detailed particulars of the performances of the same or similar ships in smooth water at the measured mile, with the particulars and conditions set forth in a Form of Return which accompanied the memorandum, or any other, more comprehensive or effectual, that might be given.

5. The actual performance of the same or similar vessels at sea, with the particulars and conditions set forth as aforesaid.

Your Committee would remark in passing, that from the date of their first appointment, they have not ceased, on every available occasion, to press this subject upon the attention of the authorities; but, up to the present time, your Committee are not aware that any experiments of the kind have been undertaken.

In the Report presented to your Association at Oxford, it is stated that a table of certain of Her Majesty's vessels, seventeen in number, had been constructed, containing the results of the best trials as conducted by the Government officers, and that it had been forwarded to the Admiralty with the request that the additional particulars of the hull and machinery might be filled in. The table, however, did not arrive in time to be inserted in their Report.

Your Committee have great pleasure in being now enabled to lay it before your Association in the state it has been received from the Admiralty. (Appendix, Table 1.) They would remark in connexion with this return, that it appears that the authorities have not been in the habit of recording either the quantity of coals consumed or the evaporation of water, and they have made application to the Admiralty that in future these desiderata may be obtained.

In compliance with the terms of the resolution appointing the Committee, viz., "That the attention of the Committee be also directed to obtaining information respecting the performance of vessels under sail, with a view to comparing the results of the two powers of wind and steam," your Committee have to state that hitherto they have been unable to obtain such comparisons in the case of merchant vessels, but in the Table given in Appendix, Table 2, particulars of one of H.M. vessels are recorded under three conditions, viz., under steam alone, under sail alone, and under steam and sail combined, and of two under the two latter conditions only.

These are especially useful, as they show the effects produced by powers brought to bear upon the hulls of vessels under the same conditions as to draft and trim, but differently applied.

In endeavouring to collect this information from officers in H.M.'s service, the Committee were desirous that the application should be made with the concurrence of the Admiralty, and a circular was accordingly issued to a selected number of officers, accompanied by a form, which they were requested to fill up and return. At the request of the Admiralty, copies of these documents were submitted for their inspection.

The circular stated that the Committee had apprized the Admiralty of the Committee's proposal to communicate with such captains and engineers of H.M.'s vessels as might be disposed to assist the British Association in obtaining facts for scientific calculations relating to the performance of ships at sea.

The form proposed was as simple as was consistent with the object of obtaining data necessary for calculation, and the Committee conceived that the time required to fill up such forms would not interfere with the duties of the respective officers. It also stated that the Committee invited the co-operation of officers for the benefit of science alone, and that one of the fundamental rules laid down by the Association in directing their labours was as follows:—

"The object of the Committee is to make public recorded facts, through the medium of the Association, which, being accessible to the public in that manner, will bring the greatest amount of science to the solution of the difficulties now existing to the improvement of the forms of vessels and the qualities of marine engines. They will especially endeavour to guard against information so furnished to them being used in any other way."

Your Committee issued the Circular and Form of Return (see Appendix, p. 198) to upwards of 200 of H.M.'s captains in commission, and to their chief engineers through the captains.

Numerous replies have been received promising returns; but the distance at which most of the vessels are stationed, namely, China, the East Indies, and America, has precluded our receiving such particulars in time for this Report. Returns, however, of seven vessels have been received, six of which are given in Appendix, Table 2; and the seventh vessel, the 'Victor Emmanuel,' being returned in a different form, is given separately in Appendix,

TABLE 10.

RÉSULTATS DE LA NAVIGATION DES PAQUEBOTS DES SERVICES MARITIMES DES MESSAGERIES IMPÉRIALES PENDANT L'ANNÉE 1859.

PAQUEBOTS	Force Nominale	Nombre de Jours [illegible]	Nombre d'Heures Moyen [illegible]	Force [illegible]	Total du Parcours	Heures de Chauffe	Heures de Marche	[illegible] Moyenne [illegible] Vapeur	Vit. Moyenne [illegible]	Détente Moyenne	[illegible]	[illegible]	Consommation de Charbon: Totale	Moyenne par Heure	[illegible] par [illegible] Mille	Par [illegible]	Par [illegible]	Consommation d'Huile et de Suif: Total	Par Cheval [illegible] 24 Heures	Vitesse Moyenne [illegible]	Vitesse [illegible]	Consommation [illegible]	Parcours [illegible]
	Ch.			Ch.	Lieues	h m	h m				Mètres	Mètres	K.	K.	K.	K.	K.	K.		Nœuds	Nœuds	K.	Mètres
Amérique	450	54	40 [illegible]	388	[illegible]	504 0	449 15	1 18	0 69	0 66	4 07	1 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2187	0 277	[illegible]	[illegible]	[illegible]	[illegible]
Thabor	470	24	[illegible]	313	[illegible]	[illegible] 50	[illegible] 0	0 66	0 65	[illegible]	4 17	0 19	[illegible]	1118	[illegible]	[illegible]	1 6	4080	0 129	[illegible]	10 10	[illegible]	[illegible]
Sinaï	[illegible]	[illegible]	18 [illegible]	[illegible]	[illegible]	178[illegible] 15	1[illegible] 0	[illegible]	0 64	0 45	4 07	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4 7	3835	0 161	[illegible]	[illegible]	115	[illegible]
Carmel	[illegible]	[illegible]	20 2[illegible]	31[illegible]	[illegible]	3[illegible] 1[illegible]	2[illegible] 50	[illegible]	[illegible]	0 42	[illegible]	[illegible]	[illegible]	[illegible]	1 3	[illegible]	4 8	8171	0 1[illegible]	10 65	1[illegible]	364	[illegible]
Danube	370	63	[illegible]	[illegible]	9572	3312 0	3018 15	[illegible]	0 65	[illegible]	[illegible]	1 23	[illegible]	[illegible]	[illegible]	5 7	3 9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cydnus	370	63	60 32	354	[illegible]	3419 25	2665 0	[illegible]	0 64	0 70	[illegible]	[illegible]	[illegible]	[illegible]	3[illegible]	3 3	[illegible]	[illegible]	[illegible]	10 15	10 46	287	19,2[illegible]
Phase	370	63	60 [illegible]	[illegible]	6177	[illegible] 40	[illegible] 35	0 61	0 62	[illegible]	[illegible]	1 13	[illegible]	[illegible]	[illegible]	3 7	[illegible]	6251	[illegible]	1[illegible] 25		310	17 [illegible]
Neva	370	63	61 42	[illegible]	[illegible]	2369 0	2215 0	0 62	0 66	0 59	4 13	1 67	[illegible]	[illegible]	[illegible]	3 9	4 0	7[illegible]	0 221	10 78	11 50	283	19,597
Pausilippe	320	26	24 02	[illegible]	8806	4254 30	2504 25	0 62	0 65	0 38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1 3	1 7	[illegible]	0 151	10 [illegible]	10 85	289	19,22[illegible]
Quirinal	320	26	23 92	294	8520	4001 45	[illegible] 35	0 66	0 65	0 38	3 90	[illegible]	[illegible] 723	140 2	114	4 6	1 9	48[illegible]	0 145	10 58	10 60	300	18,188
Euphrate	350	30	27 01	325	[illegible]	2265 25	20[illegible] 0	0 54	0 64	0 41	5 18	[illegible]	[illegible]	1717	525	5 0	[illegible]	[illegible]	0 195	9 05	..	131	12,868
Gange	300	29	26 71	[illegible]	[illegible]	[illegible] 25	2644 30	0 63	0 61	Fixe	[illegible]	1 47	[illegible]	[illegible]	[illegible]	5 4	5 8	[illegible]	0 147	9 74		126	13,019
Indus	300	50	46 59	279	9[illegible]	[illegible] 15	2075 20	0 57	0 65	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	477	5 3	5 7	[illegible]	[illegible]	10 [illegible]	10 35	382	14,518
Hydaspe	240	30	[illegible]	210	[illegible]	1113 45	3112 15	0 64	0 66	Fixe	4 54	0 51	[illegible]	[illegible]	366	4 8	5 3	[illegible]	0 223	9 54	10 07	[illegible]	17,083
Simoïs	240	46	48 55	[illegible]	[illegible]	[illegible]	[illegible] 20	0 65	0 60	0 51	4 47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4 8	2744	0 202	10 24		[illegible]	20,278
Jourdain	210	32	26 01	200	3080	1968 45	14[illegible]8 0	0 72	0 66	0 35	[illegible]	1 28	[illegible]	[illegible]	114	5 2	6 2	[illegible]	[illegible]	[illegible]	...	148	11,148
Borysthène	210	32	[illegible]	232	[illegible]	[illegible] 15	[illegible] 40	[illegible]	0 66	0 31	4 70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9 915	0 253	9 22	...	309	15,025
Méandre	210	32	30 53	220	[illegible]	[illegible] 0	28[illegible] 15	0 67	0 65	Fixe	[illegible]	[illegible]	[illegible]	110	[illegible]	[illegible]	[illegible]	[illegible]	0 222	[illegible]		[illegible]	13,717
Hermus	240	71	[illegible]	220	[illegible]	2797 10	2311 2[illegible]	0 68	0 64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0 181	[illegible]	9 70	319	17 [illegible]
Céphise	240	71	67 98	229	6250	[illegible] 45	1876 15	0 65	0 65	0 57	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	4 2	3949	0 210	[illegible]	10 55	238	23 [illegible]
Clyde	200	57	48 74	171	[illegible]	[illegible] 25	3138 10	0 48	0 65	[illegible]	3 93	[illegible]	[illegible]	872	[illegible]	4 3	[illegible]	[illegible]	0 212	[illegible]	8 95	341	16,283
Tamise	200	57	51 14	170	7621	3108 1[illegible]	2118 0	0 50	0 64	0 51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	3181	0 158	9 45	9 65	[illegible]	21,129
Mersey	200	29	[illegible]	188	[illegible]	[illegible] 35	[illegible]	0 41	0 65	0 38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8 75	9 50	366	15,141
Alexandre	2[illegible]	21 5	19 [illegible]7	200	[illegible]	[illegible] 4[illegible]	[illegible]	0 11	0 64	[illegible]	4 10	0 14	[illegible]	[illegible]	[illegible]	1 1	[illegible]	1 017	0 187	8 [illegible]	[illegible]	181	11,532
Caire	220	21 5	13 35	108	[illegible]	1043 45	1[illegible]7 0	0 33	0 70	0 17	4 10	0 13	[illegible]	[illegible]	[illegible]	1 7	[illegible]	[illegible]	0 179	8 31		136	12,730
Louqsor	220	21	21 [illegible]	221	5316	[illegible] 40	18[illegible] 0	0 47	0 65	0 33	4 12	[illegible]	1,838,074	[illegible]	315	4 5	1 5	[illegible]	[illegible]	8 07	.	372	14,893
Nil	220	21	[illegible]	[illegible]	47[illegible]	1936 50	1791 40	0 50	0 65	0 55	4 11	0 12	1 751 580	[illegible]77	[illegible]	4 4	4 6	2886	0 175	8 63	9 0	456	12,172
Osiris	220	21 5	20 15	[illegible]	[illegible]	[illegible] 1[illegible]	[illegible]27 1[illegible]	0 43	0 60	0 33	4 05	0 10	1 911,0[illegible]	821	294	3 7	[illegible]	[illegible]	0 185	8 [illegible]	9 10	343	16,198
Capitole	[illegible]	24	[illegible]	1[illegible]5	7536	5550 16	21[illegible]8 55	0 65	0 67	0 40	3 46	0 10	2 685 20[illegible]	1114	354	6 5	6 7	3225	0 160	9 38	9 70	328	16,016
Vatican	2[illegible]	24	[illegible]	1[illegible]	7248	3213 15	2257 15	0 62	0 70	0 33	3 32	[illegible]	2 438,181	1080	333	5 4	[illegible]3	2785	0 148	9 [illegible]3	1[illegible] 27	[illegible]	18 [illegible]
Henry IV.	200	45	45 45	2[illegible]2	[illegible]	3344 35	233[illegible] 30	0 62	0 64	0 50	3 70	1 6[illegible]	1 862 042	7[illegible]	201	[illegible]	3 6	[illegible]	[illegible]	8 20		[illegible]7	15,551
Sully	200	45	45 74	203	3182	1725 0	122[illegible] 30	0 60	0 63	0 60	3 41	1 78	1,[illegible]	825	318	4 1	1	2181	0 [illegible]13	8 0	8 05	402	13,818
Bosphore	180	26 5	25 57	162	6[illegible]51	2783 0	1941 20	0 60	0 57	0 40	2 15	0 24	1 616 700	812	2[illegible]7	1 5	5 1	2002	0 206	9 35	10 06	247	22,408
Hellespont	180	26 5	20 [illegible]1	152	5762	1[illegible] 40	1162 55	0 55	0 59	0 33	[illegible]7	0 13	1 [illegible],820	801	273	4 9	4 8	1895	0 217	9 70	10 0	237	23,356
Oronte	180	25	23 82	171	5 [illegible]	2373 50	1702 0	0 53	0 63	0 53	2 05	0 17	1 155,374	855	288	1 7	[illegible]	2[illegible]27	0 [illegible]05	8 83	9 85	301	18,408
Philippe Auguste	180	2[illegible] 5	20 [illegible]8	177	61[illegible]8	2839 0	2123 15	0 51	0 60	Fixe	2 88	0 13	1,[illegible]9 310	899	2[illegible]1	4 9	5 0	3532	0 222	9 16	10 15	256	19,393
Mérovée	180	25	[illegible]	161	[illegible]	2179 50	1740 0	0 47	0 65	0 34	2 00	0 13	1 628 [illegible]	849	[illegible]	4 7	5 2	2700	0 185	8 80	...	324	17,104
[illegible]	180	46	45 06	176	7[illegible]	3573 0	2641 45	0 61	0 63	0 45	3 55	1 41	2 528 295	881	303	4 9	5 0	3122	0 170	8 66	...	330	16,836
Mitidjah	160	50	47 16	151	7[illegible]	3098 50	24[illegible]5 30	0 58	0 66	0 46	3 68	[illegible]	1 757,607	730	21[illegible]	4 5	4 8	3655	0 227	9 07	10 0	238	23,300
Balkan	160	28	25 [illegible]	147	[illegible]	2855 10	2003 20	0 80	0 64	0 40	2 60	0 13	1 [illegible]2,35[illegible]	844	276	5 2	5 7	4165	0 311	9 16	...	268	20,654
Taurus	160	28	25 [illegible]2	16[illegible]	6314	1763 35	1570 25	0 [illegible]	0 65	0 65	2 38	0 11	1,297,669	823	213	5 1	5 1	2591	0 246	10 11	...	194	28,678
Sphinx	160	30 5	21 80	130	5117	2754 0	1813 30	0 38	0 66	Fixe	3 10	0 10	1,150,685	794	282	4 9	6 1	3059	0 260	8 42	...	323	17,151
Tage	160	22 5	19 98	142	5591	2600 35	20[illegible]0 20	0 39	0 68	...	3 58	0 [illegible]6	1,511,008	732	270	4 5	5 1	4385	0 317	8 10	...	334	16,605
Télémaque	160	22 5	23 88	169	5815	2153 0	1995 15	0 58	0 67	. .	3 64	0 [illegible]8	1,559,560	781	267	4 8	4 0	2787	0 209	8 74	...	284	19,518
Amsterdam	150	24	20 16	126	4138	1818 45	1491 10	0 40	0 63	0 40	3 [illegible]6	0 49	869,125	582	210	3 8	4 6	2514	0 270	8 32	...	246	22,563
Périclès	120	27 5	27 91	121	5719	2214 35	1023 40	0 56	0 64	0 40	2 46	0 12	1,003,951	553	180	4 6	4 5	2777	0 288	8 00	...	187	29,714
TOTAUX	11,120	...	...	10,257	305,860	125,136	99,206 30	...	...	...			108,784,549	50,443	16,357	.		202,036	9 365		...	15,487	801,468
MOYENNES	240	...	...	223	6,649	2,720 20	2,160 35	.	.	.	3 82	0 70	2,364,861	1,09[illegible]	355	4 5	4 9	4,392	0 203	9 25	..	336	17,423

TABLE II

RÉSULTATS DE LA NAVIGATION DES PAQUEBOTS DES SERVICES MARITIMES DES MESSAGERIES IMPÉRIALES PENDANT L'ANNÉE 186[illegible]

PAQUEBOTS.	Force Nominale.	Nombre de Tours Correspondants.	Nombre de Tours Moyen d'après le Compteur.	Force Nominale réalisée correspondant à ce Nombre de Tours.	Total du Parcours.	Heures de Chauffe.	Heures de Marche.	Tension Moyenne de la Vapeur.	Vide Moyen du Condenseur.	Ouverture des Registres de Vapeur.	Introduction Moyenne de Vapeur dans les Cylindres.	Tirant d'Eau Moyen.	Différence de Tirant d'Eau.	Consommation du Charbon. Totale.	Moyenne par Heure.	Moyenne par Lieue Marine.	Par Cheval Nominal et par Heure.	Par Force de Cheval Nominal réalisée et par Heure.	Consommation d'Huile et de Suif. Totale.	Par Cheval et par 24 Heures.	Vitesse Moyenne sur la Base directe.	Vitesse Moyenne Estimée.	Consommation par lieue [illegible]	Parcours en Mètres fait avec 1 kilo de Charbon [illegible] de Vitesse.
	Chevaux			Chevaux	Lieues	h m	h m					Mètres	Mètres	Kilo	Kilo	Kilo	Kilo	Kilo	Kilo	Kilo	Nœuds	Nœuds	Kilo	Mètres
Guienne	460	18	15·40	[illegible]	[illegible]	2062 35	2313 0	0·90	0·63	En grand	0·50	4·80	0·29	5,180,298	2210	675	4·8	5·7	7887	0·178	9·96		750	10,085
Navarre	460	18	15·15	387	725[illegible]	2296 15	2206 10	0·81	0·63	0·81	0·57	4·05	0·147	4,972,471	2253	684	4·9	5·8	9368	0·221	9·86		671	9,726
Estramadure	460	18	15·07	385	3909¾	1226	1171 15	0·84	0·64	En grand	0·45	4·77	0·02	2,783,190	2376	711	5·1	6·1	6378	0·230	10·01	...	675	9,655
Béarn	460	18	14·12	313	[illegible]	1735 10	1530 15	0·79	0·65	ditto	0·58	4·86	0·14	3,401,543	2264	711	4·9	7·2	4366	0·140	9·55	9·00	630	8,705
Amérique	450	54	46·89	[illegible]	[illegible]	1849 45	1539 45	0·69	0·58	0·50	0·50	4·97	0·995	2,857,348	1855	573	4·1	4·7	4151	0·113	9·70	..	494	11,245
Thabor	370	24	20·30	313	7800	2478 55	2324 50	0·70	0·647	0·97	0·50	4·15	0·08	3,217,177	1396	414	3·7	4·4	4474	0·125	10·08		333	10,640
Sinaï	370	24	20·40	314	3234½	1103 35	962 35	0·58	0·59	0·79	0·65	3·90	0·14	1,452,724	1163	450	3·9	4·0	2732	0·178	9·77		381	14,575
Carmel	370	24	20·88	322	7693½	3364 30	2297 10	0·65	0·63	0·86	0·57	3·90	0·247	3,184,899	1380	402	3·7	4·3	5828	0·164	10·30	10·80	308	18,045
Danube	370	63	57·60	337	52[illegible]	1906	1732 55	0·47	0·64	0·55	0·00	4·16	1·25	2,700,294	1558	519	4·2	4·6	5140	0·192	9·00	9·00	519	10,698
Cydnus	370	63	60·11	347	6864½	2579	2054 40	0·63	0·63	0·80	0·65	4·08	1·21	2,401,009	1146	348	3·1	3·3	7488	0·231	9·85	10·65	203	10,615
Phase	370	63	62·71	308	9542	3350 10	2705 15	0·65	0·65	0·83	0·59	3·90	1·33	3,906,388	1307	408	3·7	3·8	8456	0·196	10·25	...	315	17,600
Neva	370	63·4	61·63	300	10784	3221 15	3022 10	0·63	0·65	0·56	0·58	4·15	1·61	4,183,191	1379	487	3·7	3·8	6657	0·142	10·67	10·82	276	20,107
Euphrate	350	30	28·25	329	111[illegible]½	4140 35	3361 0	0·64	0·67	0·48	0·64	5·83	0·99	5,744,066	1709	516	4·9	5·2	9906	0·202	9·95	10·50	422	14,160
Pausilippe	320	26	23·36	257	8704	4439 20	2514 55	0·63	0·65	0·75	0·62	3·97	0·43	3,142,650	1249	357	3·9	4·3	4735	0·141	10·50	10·65	262	21 145
Quirinal	320	26	23·40	288	8272	3380	2331 40	0·68	0·65	0·68	0·62	3·80	0·36	2,980,960	1278	360	3·9	4·4	3641	0·117	10·65	10·95	257	21,586
Gange	300	29	26·58	275	7175	2935 45	2254 0	0·59	0·60	En grand	0·65	5·19	1·32	3,430,205	1521	477	5·0	5·5	5138	0·182	9·55	..	424	13,085
Indus	300	50	44·18	265	11088	4350 35	3579 0	0·53	0·63	ditto	0·50	5·01	0·80	5,703,603	1565	513	5·2	5·9	9062	0·222	9·56		456	12,180
Sanarouge	250	26·2	22·91	218	3190¼	1213 20	1002 0	0·82	0·66	0·15	0·55	3·08	0·00	1,202,250	1154	303	4·6	5·2	2700	0·232	8·80	.	413	13,450
Hydaspe	210	30	25·33	202	8323¼	3388	2777 15	0·63	0·67	En grand	0·63	4·61	0·49	3,300,035	1190	306	4·9	5·8	5770	0·207	9·00	9·37	307	13 985
Simois	240	46	48·07	251	11181½	4456 15	3329 10	0·67	0·686	0·85	0·52	4·52	0·81	3,449,913	1035	309	4·3	4·1	6702	0·201	10·07	10·50	246	22,515
Jourdain	240	32	25·56	216	10033	4466 40	3233 0	0·70	0·68	En grand	0·65	4·94	1·28	3,854,962	1170	354	4·8	5·4	4951	0·151	9·15	...	372	14,920
Borysthène	240	32	29·84	224	9138¼	3379 35	2957 20	0·65	0·68	0·58	0·70	4·78	0·78	3,476,091	1175	381	4·8	5·2	7005	0·236	9·27	9·40	358	15,480
Méandre	240	32	28·95	217	6778¾	2365	2175 0	0·67	0·65	0·08	0·70	4·74	0·67	2,630,910	1209	387	5·0	5·5	8773	0·165	9·35	..	359	15,46[illegible]
Hermus	240	72	64·92	216	7065	2647 40	2226 10	0·68	0·63	En grand	0·50	3·58	1·25	2,278,148	1023	321	4·2	4·7	8698	0·175	9·55	9·95	286	19,385
Cephise	240	73	67·69	225	7561	2553 30	2372 40	0·73	0·65	0·78	0·57	3·50	1·26	2,186,445	921	288	3·8	4·0	4775	0·201	9·56	10·35	256	21,075
Alexandre	220	21·5	19·30	197	5410¾	2252 30	2069 0	0·30	0·65	0·52	0·55	4·06	0·075	2,022,950	969	372	4·4	4·9	2864	0·149	7·77	9·10	500	11,670
Caire	220	21·5	20·05	205	2620¾	1028 50	916 30	0·40	0·62	...	0·50	4·06	0·18	838,067	916	318	4·1	4·4	1111	0·132	8·57	8·00	353	15,735
Louqsor	220	21	20·72	217	7205¼	2704 40	2576 30	0·46	0·65	0·97	0·60	4·12	0·072	2,015,797	1016	363	4·6	4·6	5008	0·212	8·40		417	13,315
Nil	220	21	20·23	211	63[illegible]4	[illegible]	2122 25	0·45	0·65	0·85	0·45	4·09	0·13	2,305,873	952	360	4·3	4·5	3327	0·140	7·92	8·78	465	11,925
Osiris	220	21·5	20·58	210	3330	1593	1396 0	0·46	0·60	0·74	0·01	4·08	0·09	1,182,747	854	303	3·8	4·0	3134	0·244	8·16	...	313	16,195
Clyde	200	57	49·20	172	7160⅛	2673	2165 15	0·53	0·68	0·73	0·66	4·00	2·17	2,253,852	914	315	4·5	5·3	4362	0·212	8·72		334	16,605
Tamise	200	57	[illegible]	177	[illegible]	2170 50	1600 40	0·62	0·65	0·85	0·50	3·89	2·11	1,540,498	927	306	4·6	5·2	2115	0·152	9·02	9·35	307	18,075
Mersey	200	29	26·18	180	9681	3880 [illegible]	3104 10	0·39	0·64	0·77	0·62	4·43	0·77	3,325,494	976	312	4·8	5·4	3382	0·110	8·55	8·70	380	14,[illegible]
Capitole	200	21	20·[illegible]5	167	8756	[illegible]	2782 15	0·66	0·60	En grand	0·65	5·13	0·87	3,[illegible]03,540	1075	339	5·3	6·4	2945	0·126	9·45	9·50	309	17,040
Vatican	200	24	19·23	16[illegible]	8542¾	[illegible] 25	2831 25	0·64	0·66	ditto	0·69	3·40	0·008	2,766,963	977	324	4·8	6·1	2964	0·125	9·05		320	17,325
Henry IV	200	45	45·19	200	3260¾	1924 40	1270 10	0·66	0·65	0·80	0·50	3·61	1·57	1,046,465	823	321	4·1	4·1	3014	0·284	7·70		438	12,060
Sully	200	45	47·00	212	6515½	2919 10	2195 30	0·64	0·64	0·85	0·40	3·57	1·66	1,759,200	801	270	4·0	3·7	3795	0·207	8·00		276	20,100
Bosphore	180	26·5	25·77	175	7[illegible]04¼	31[illegible]3	2225 10	0·61	0·59	0·81	0·60	2·[illegible]0	0·26	1,901,926	854	270	4·7	4·8	8269	0·196	9·45	9·70	246	22,545
Oronte	180	25	24·89	179	4602¼	1764 25	1260 30	0·65	0·63	0·95	0·47	2·91	0·08	1,075,614	851	264	4·7	4·7	1546	0·163	9·66	...	230	24,160
Philippe Auguste	180	26·5	25·3[illegible]	171	4284¾	1787	1420 40	0·52	0·60	En grand	0·62	2·92	0·14	1,237,012	877	288	4·8	5·1	1892	0·177	9·05	...	285	19,433
Mérovée	180	25	21·93	168	1243	532 35	474 20	0·12	0·67	0·59	0·66	3·00	0·09	411,000	866	330	4·8	5·4	770	0·216	7·86	8·00	433	12,815
Cheliff	180	46	42·22	165	5616¼	3231 40	2423 0	0·55	0·59	En grand	0·60	3·53	1·37	2,059,100	850	306	4·7	5·1	2409	0·136	7·00	.	6[illegible]0	9,155
Mitidjah	160	50	48·88	156	5408	2467 20	1991 0	0·65	0·65	0·88	0·55	3·72	0·88	1,598,783	803	294	5·0	5·1	2847	0·214	8·15	8·27	380	15 305
Balkan	160	28	26·20	150	7129¾	3478 30	2276 0	0·73	0·65	0·94	0·60	2·70	0·13	2,084,254	915	291	5·7	6·1	4451	0·205	9·10		268	20,715
Taurus	160	28	27·44	156	6393¼	2580 40	1797 10	0·77	0·65	0·71	0·48	2·41	0·10	1,190,951	716	231	4·6	4·7	3072	0·230	9·60		205	27,060
Sphinx	160	30·5	24·33	137	4677½	2462 25	1747 40	0·39	0·65	0·68	0·80	3·05	0·33	1,300,467	747	279	4·6	6·8	3157	0·270	8·02		352	15,775
Tage	160	22·5	20·16	143	3931½	1956 20	1469 20	0·35	0·65	0·07	0·68	3·55	0·21	1,093,303	732	276	4·6	5·1	2807	0·287	8·05		348	15 965
Télémaque	160	22·5	24·39	173	5433¾	2016 10	1610 45	0·50	0·67	0·587	0·62	3·01	0·27	1,417,200	782	258	4·8	4·5	2789	0·231	9·02		279	21,410
Amsterdam	150	24	19·85	124	2437	1186 10	944 50	0·40	0·657	0·60	0·60	3·16	0·38	588,511	623	240	4·1	5·0	1287	0·204	7·75	...	325	77,000
Périclès	120	27·5	27·86	121	6110	2150 25	2008 10	0·60	0·64	0·97	0·60	2·38	0·16	1,234,085	614	201	5·1	5·0	2135	0·212	9·12	..	196	28,220
TOTAUX	13,030	..	...	11,748	328,020	132,722 25	100,160 35	...	...	...	...	...	..	125,048,359	59,300	19,200	...	...	215,443	9 365	...	...	18,807	819,446
MOYENNES	260		...	235	6,560	2,654 27	2,123 12	...	...	...	...	...	..	2,518,967	1,186	384	4·5	5·0	4,309	0·187	9·20	9·75	366	16,380

TABLE 3.—PERFORMANCE OF H.M.S. "VICTOR EMANUEL" AT SEA.

Date and Nature of Experiment.	Duration.	Draught of Water. Forward.	Draught of Water. Aft.	Draught of Water. Mean.	Displacement.	Area of Midship Section, immersed.	Boilers. Number used.	Boilers. Pressure per sq. in.	Engines. Mean pressure on piston.	Engines. Number of Revolutions per minute.	Engines. Indicated H.P.	Engines. Full Speed, Degree of Expansion, &c.	Screw. Speed of Screw per hour.	Screw. Speed of Ship per hour.	Screw. Slip per hour.	Screw. Slip per cent.	Coals. Per hour.	Coals. Per hour.	Coals. Per day.	Coals. Per I H P. per hour.	Coals. Per Knot.	Coals. Distance run with 1 ton.	Coals. Kind and Quality.	Speed³ × Midship sec. / Indicated H. P.	Speed³ × Displacement⅔ / Indicated H. P.	Force of Wind.	State of Sea.	Direct on of Wind as regards Ship.	Sail set.
	Hours.	ft. in.	ft. in.	ft. in.	Tons.	sq. ft.		lbs.	lbs.				Knots.	Knots.	Knots.		lbs.	cwt	Tons.	lbs.	cwt	Knots							
Trial at Stokes' Bay, November 28, 1856	Not stated.	17 2	20 8	18 11	3452	785	4	20	Not stated	55½	2098	Full speed	14 32	11·92	2 4	16 7	Not stated.	Not stated.	Not stated.	Not stated	Not stated.	Not stated	Not stated	633	183	Not stated	Not stated	Not statrd	None.
„ December 30, 1856	„	17 3	20 11	19 1	3516	796	4	20	„	56	2122	„	14 45	12 0	2 45	16 9	„	„	„	„	„	„	„	648	188	„	„	„	Ditto.
Trial with four-bladed screw, January 15, 1858	„	17 5	20 11	19 2	3544	800	4	20	„	51	2079	„	13 16	11 82	1 34	10 2	„	„	„	„	„	„	„	635	184	„	„	„	Ditto.
„ „ February 15, 1858	„	17 5	21 0	19 2½	3544	800	4	20	„	51	2219	„	13 16	11·71	1 15	11 0	„	„	„	„	„	„	„	578	168	„	„	„	Ditto.
„ „ February 26, 1858	„	17 5	21 0	19 2½	3544	800	2	20	„	42 4	1250	Half power, Two boilers.	10 94	9 93	1 01	9 2	„	„	„	„	„	„	„	626	182	„	„	„	Ditto.
Berehaven to Gibraltar, March 9, 1859	10	23 1	24 9	23 11	5135	1060	3	19	10 62	36 5	749	Throttled	9 42	6 2	3 2	31 1	3500	31½	37½	4 6	5·04	3 9	„	337	163	2 to 3	Mod. swell	3 points on bow	Ditto.
„ „ March 16, 1859	10½	23 7	24 3	23 5	4955	1033	3	17	10·54	39	794	„	10 06	8 5	1 56	15 5	3651	32 6	39 1	4 5	3 83	5 2	„	799	224	1 to 2	Smooth water	4 points on bow	Fore & aft sails.
Steaming through the Gulf of Gibraltar, March 17, 1859	.	22 7	24 3	23 5	4955	1033	3	16	11 81	44	1196	Expansively and Throttled	11 35	7·5	3 85	21 3	5656	50 5	60 6	4 7	6 73	2 9	„	364	102	5 to 6	Mod. swell	Ahead	None.
„ „ „ July 12, 1859	9	22 9	23 0¾	22 10⅞	4947	1032	3	15	11 02	40	851	Expansively	10·32	8 75	1 57	15 2	4256	38	45 5	4 9	4 47	2 3	Good Welsh	744	200	...	Smooth water	Calm	Ditto.
Alexandria to Cape Passero, with fleet, August 15, 1859	...	22 10½	24 7	23 8¾	5067	1050	2	15	6 32	28	341	Expansively, with link motion, & Throt.	7 22	4 6	2 62	30 3	1568	14	16·8	4 5	3·04	6 5	„	220	84	3	Long swell	Ahead	Ditto.
„ „ „ August 16, 1859	...	22 10½	24 7	23 8¾	5067	1050	2	16	6 41	28	346		7 22	5 0	2 22	30 7	1904	17	20 4	5 4	3 4	5 8	„	379	106	...	„	Calm	Ditto.
Malta to Gibraltar with fleet, September 18, 1859	...	23 5	25 1	24 3	6255	1079	3	13	14 10	38	1041	„	9 8	3 0	6·8	69·4	5572	49 75	59 7	6 3	16·58	1·2	„	27	7 8	7 to 8	Heavy chopping sea.	4 points on bow	Fore & aft sails.
Malta to Gibraltar, *Princess Royal* in tow, Sept. 21, 1859	2	23 4	25 0	2[illegible] 2	6255	1074	3	15	13 87	43	1151	„	11·00	8·0	3 09	27 9	5712	51·0	61 2	4 9	6 37	3 1	„	477	134	1 to 2	Smooth	1 point before beam.	Ditto.
„ „ „ Sept. 22, 1859	4	23 3	24 11	[illegible] 1	6195	1069	3	15	12·29	36	854	„	9·20	4 5	4 79	51·5	2856	25 5	30 6	3 3	5 60	3 5	Welsh very small	114	32	3	Mod. swell	3½ points on b	Ditto.
Corfu to sea, ship's bottom very foul, June 4, 1860	7½	23 10	25 0	[illegible] 11	6135	1061	2	18	8·16	33	519	„	8·51	5 8	2 7	31 7	2240	20 0	24 0	4 3	3 44	5 8	Welsh very good	398	112	1 to 2	Slight swell	4 points on bow	Ditto.
Zanti to Argostoli, June 11, 1860	5	23 0	24 8	[illegible] 10	5105	1056	2	18	10·75	38	788	„	9 8	6 8	3 0	30 6	2240	20·0	24·0	2·84	2 94	6 8	„ „	421	119	...	Smooth	Calm	None.
Steaming out of Argostoli, June 14, 1860	2¾	22 9	24 11	23 10	5105	1056	2	17	13·27	39	999	„	10·06	7 0	3 06	30 4	2296	20 5	24 6	2·3	2 92	6 8	„ „	362	102	...	„	„	Ditto.
Malta to Navarino (spare screw), July 4, 1860	3	23 1	25 5	24 3	6255	1079	2	18	13·6	42	1103	„	10 84	7 5	3 34	30·8	2240	20·0	24·0	2 3	2·66	7 5	Middling Welsh.	412	115	5	Mod. swell	5¾ points on b.	All plain sail, Dble. reefed topsls.
„ „ „ July 28, 1860	4	22 7	24 6	23 6¼	5000	1040	2	15	16 83	42	1361	„	10·73	7 5	3 23	30 8	3136	28 0	33 6	2 3	3 73	5·4	Good Welsh	322	90 6	2	„	On the bow	No sail.
„ „ „ September 7, 1860	3¾	22 10	24 7	23 8½	5060	1049	2	17	10 32	34	677	„	8 69	7 0	1 69	19 4	2240	20 0	24 0	3 3	2 85	7·0	„	543	149	1 to 2	Slight swell	On the quarter	To weather, studding sails.
„ „ „ September 13, 1860	10½	23 0	24 3	23 7½	5030	1044	2	15½	6 1	32	500	„	8 17	4 8	3 37	41 2	2083	18 6	22 3	4 2	3 87	5 2	Small and bad	230	64 9	3	Smooth	Head wind	None.
„ „ „ September 14, 1861	1	22 10	24 6	23 8	5045	1047	2	15½	10 12	35	684	„	8 94	4 4	4 54	50·8	3808	34·0	40 8	5 5	7 72	2 6	„	130	36·6	4	Heavy headsw	„	Ditto.
Beyrout to Corfu, October 14, 1860	[illegible]¾	23 0	24 8	23 10	5105	1056	2	14	9 03	34	592	„	8 69	6 3	2 39	27 5	2660	23 75	28 5	4 5	3 7	5 3	Price's Tillery very good.	446	125	0 to 2	Smooth	„	Ditto.
„ October 15, 1860	10½	23 0	24 8	23 10	5105	1056	2	13	8 57	34	562	„	8 69	6 1	2 59	29·7	2716	21 25	29 1	4 8	3·9	5 03	„	426	119	1 to 3	„	5¾ points on b	All plain sail.
„ October 17, 1860	5	23 0	24 8	23 10	5105	1056	2	14	8 53	33	542	„	8 43	6 0	2 43	28 8	2352	21 0	25 2	4 7	3 5	5 7	„	420	118	0	„	Calm	None.

Engines.

Nominal horse power ... = 600
Diameter of cylinder = 76½ inches.
Length of stroke ... = 3 feet 6 inches
Pressure per square inch on safety valves = 20 lbs
Steam cut off by slides at ·653 of the stroke (mean).

Screw Propellers.

	Original. ft. in.	Spare. ft. in.
Diameter	18 2	18 1
Length	3 1	3 0
Pitch	26 2	25 11

Boilers.

Area of fire-grate = 435 square feet.
Area of opening over bridges = 92 4 „
„ through tubes = 60 7 „
Area of chimney = 45 1 „
Total heating surface = [illegible]1400 „

Contents of steam space = 2592 cubic feet.
Total water at working height = 97 7 tons.
Machinery by Maudslay, Sons, and Field, made in 1856.
Engines horizontal direct.

TABLE 4.

RETURN OF SEVEN TRIALS ON THE MEASURED MILE IN STOKES BAY, OF H.M. SHIP "VICTOR EMANUEL."

Victor Emanuel.	Full Power of Boilers 2 Bladed Screw.	Full Power of Boilers Screw ditto.	Full Power of Boilers 4 Bladed Iron Screw, made at Portsmouth Yard.	Full Power of Boilers Screw ditto	Half Power of Boilers Screw ditto.	Full Power of Boilers Screw 2 Bladed	Half Power of Boilers Screw ditto.
Date of Trial	28 Nov. 1856.	30 Dec. 1856.	15 Jan. 1858.	15 Feb. 1858	26 Feb. 1858.	9 Sept. 1858.	9 Sept. 1858.
Trial made in	Stokes Bay.	Stokes Bay.	Stokes Bay.	Stokes Bay.	Stokes Bay.	Stokes Bay.	Stokes Bay.
Horse Power by Admiralty Rule	600 Horses.	600 Horses.	600 Horses.	600 Horses.	600 Horses.	600 Horses.	600 Horses.
Maker's Name			Maudslay,	Sons &	Field		
Draught of Water (Forward)	17 ft. 2 in.	17 ft. 3 in.	17 ft. 5 in.	17 ft. 5 in.	17 ft. 2 in.	23 ft. 3 in.	23 ft. 3 in.
Ditto (Aft)	20 ft. 8 in.	20 ft. 11 in.	20 ft. 11 in.	21 ft. 0 in.	21 ft. 2 in.	25 ft. 0 in.	25 ft. 0 in.
Weight on Safety Valve per square inch	20 lbs.	20 lbs.	20 lbs.	20 lbs.	20 lbs.	20 lbs.	20 lbs.
Pressure of Steam in Boilers (per sq. in.) by Guage	20 lbs.	18 to 20 lbs.	20 lbs.	20 lbs.	20 lbs.	20 to 21 lbs.	19 to 20 lbs.
Vacuum in Condensers (Forward)	23½	23	23	23½	23½	23	24
Ditto (Aft)	23½	23	23½	23	24	23	24
Number of Revolutions of Engines, Mean	55½	56	51	51	42·4	56 833	45 875
Mean Pressure on Cylinders per square inch	19·58 lbs.	19·63 lbs.	21·12 lbs.	22·536 lbs.	15·28 lbs.	22·12 lbs.	14 42 lbs.
Indicated Horse Power	2098·28	2122·6	2079·8	2219·15	1250·90	2427·4	1277·32
Speed of Ship, Knots	11·922	12 009	11·826	11 713	9 932	10·874	9 075
Weather, Force of	No. 3.	No. 3 to 4.	No. 2 to 3	No. 4 to 5.	No. 4.	No. 4.	No. 4.
Wind by Admiralty Standard	Starboard Beam.	Port Bow when down the course.	Direct ahead when down the course.	Ahead when up course.	On port bow when up course.	On port bow down. course.	On port bow down course.
State of the Sea			Smooth.	Smooth.	Smooth.		
Ship if Rigged, or otherwise	Not Rigged.	Not Rigged.	Not Rigged.	Not Rigged.	Not Rigged.	Rigged.	Rigged.
Weights on Board	Not Known.	Not Known.	Not Known.	Not Known.	Not Known.	Not Known.	Not Known.
Propeller.							
Description	2 Bladed.	2 Bladed.	4 Bladed Common	4 Bladed. form of	4 Bladed. Screw.	2 Bladed.	2 Blades.
Diameter	18·2	18·2	18·2	18·2	18·2	18·2	18 2
Pitch	26·2	26·2	26·0	26·0	26·0	26·2	26·2
Length	3·1	3·1	3·1	3·1	3·1	3·1	3·1

Area of Midship Section at Mean Draft of Water of 19 ft. 2 in. = 784·25 square feet. Ditto at Draft of Water of 24 ft. 2in. = 1000·0 square feet.

Guns, 91. Length between Perpendiculars, 230 ft. 3 in. Tonnage, 3086. Breadth (Extreme), 55 ft. 4 in.

TABLE 6

L. & N. W. R.

CHESTER AND HOLYHEAD RAILWAY—STEAMBOAT DEPARTMENT

A Return of the Speed, and Consumption of Coal of the Express and Cargo Boats, under regulated Conditions of Time, Pressure, and Expansion for the undermentioned period.

Vessel.	Date.	No. of Trips run.	Passages: Longest.	Passages: Shortest.	Passages: Average.	Average Rate of Speed.	Actual Weight on Valves.	Average Pressure Worked at.	Proportion of Steam in Cylinder.	Coals Consumed: Per Trip, including getting up Steam, and while lying at Holyhead.	Coals Consumed: Per Hour, including raising Steam, Banking Fires, &c.	Coals Consumed: Per Hour exclusive of raising Steam, Banking Fires, &c.	Remarks.
			h. m.	h. m.	h. m.	Miles	lbs	lbs.		T. cwt. lb	T. cwt. lb	T. cwt. lb	
Express Boats	1860.												
Anglia	1st Jan. to 31st March ..	66	6 5	4 8	4 43	13·35	15	13	[illegible]	12 13 8	2 13 67	2 7 60	
" ...	1st April to 30th June ..	58	5 25	4 3	4 34	13·79	16	13	[illegible]	12 4 80	2 13 65	2 7 26	
" ...	1st July to 30th Sept. ...	29	6 15	4 17	5 6	12·35	15	12	[illegible]	12 15 29	2 10 5	2 4 40	
" ...	1st Oct. to 31st Dec.	66	6 20	4 20	4 45	13·26	16	12½	[illegible] and [illegible]	13 5 32	2 16 95	2 9 84	
Cambria	1st Jan. to 31st March ...	28	5 14	4 16	4 39	13·54	15	14	[illegible]	12 17 6	2 15 27	2 0 62	
"	1st July to 30th Sept. ...	1	6 45	From Liverpool		14·15	14	13	[illegible]	17 7 0	2 11 45	2 6 104	From Liverpool to Holyhead after lengthening
Scotia	1st Jan. to 31st March ...	60	6 15	4 10	4 14	13·30	15	12¼	[illegible] and [illegible]	14 9 102	3 1 21	2 12 12	
"	1st April to 30th June ..	79	5 10	4 8	4 36	13·60	15	12¾	[illegible] and [illegible]	13 19 6	3 0 74	2 9 10	
"	1st July to 30th Sept. ..	48	6 6	4 15	4 38	13·59	15	13	[illegible] and [illegible]	13 15 46	2 19 40	2 12 53	
"	1st Oct. to 31st Dec.	38	6 35	4 18	4 40	13·21	15	12¾	[illegible] and [illegible]	13 15 28	2 17 63	2 11 3	
Telegraph	1st April to 30th June .	17	4 38	4 5	4 20	14·05	10	9	Nil	14 19 10	3 6 71	2 19 66	
"	1st July to 30th Sept.	79	5 33	4 11	4 29	14·05	10	9	Nil	13 11 91	3 0 70	2 13 51	
"	1st Oct. to 31st Dec. . .	50	6 30	4 16	4 14	13·50	10	9	Nil	14 3 71	2 10 103	2 13 15	
Goods Boats:													
Hibernia	1st Jan. to 31st March	56	8 45	5 43	6 34	10·06	15	8½	[illegible]	15 0 66	2 5 77	2 1 108	
"	1st April to 30th June .	76	8 0	5 45	6 24	10·92	15	8	[illegible]	14 9 22	2 5 21	1 16 70	
"	1st July to 30th Sept. .	78	8 22	5 35	6 34	10·66	15	7¾	[illegible]	14 8 91	3 3 110	2 0 92	
"	1st Oct. to 31st Dec.	73	10 0	5 15	6 56	10·63	15	8½	[illegible]	15 4 46	2 3 101	1 19 4	
Cambria	1st Oct. to 31st Dec.	29	7 25	4 55	5 44	12·21	15	10	[illegible]	12 11 51	2 3 96	1 18 30	
Ocean	1st Jan. to 31st March .	40	10 30	6 45	8 2	8·71	10	8¾	Nil	11 9 81	1 8 62	1 4 101	
"	1st April to 30th June ..	4	8 45	5 50	6 57	10·07	10	8½	Nil	10 5 84	1 9 67	1 6 81	
Hercules	1st Jan. to 31st March ..	33	10 40	6 15	7 52	8·89	12	10¾	Nil	9 6 74	1 3 78	1 1 20	
"	1st April to 30th June .	23	8 60	6 0	7 2	9·95	12	11	Nil	8 17 60	1 5 27	1 2 14	
"	1st July to 30th Sept. ..	26	11 40	6 0	7 3	9·91	12	11		8 5 70	1 3 55	1 0 73	
"	1st Oct. to 31st Dec. .. .	37	10 10	6 17	7 49	9·39	12	12½	Nil	8 14 28	1 2 32	0 19 102	
Sea Nymph	1st Jan. to 31st March ...	54	9 15	5 25	6 30	10·52	12	10¼	1st & 2nd grade	11 15 58	1 16 45	1 13 16	
"	1st April to 30th June .	78	8 50	5 30	6 36	10·60	12	10¼	1 and 2 grade and full speed	10 19 53	1 13 13	1 9 84	
"	1st July to 30th Sept. .	78	7 55	5 25	6 26	10·88	12	10¼	1st & 2nd grade	11 4 72	1 14 102	1 11 18	
"	1st Oct. to 31st Dec. . .	49	10 20	5 35	6 50	11·14	12	10¼	1st grade	12 5 14	1 15 99	1 12 40	

TABLE 7.—CHESTER AND HOLYHEAD—STEAMBOATS.

Consumption of Coal for the 12 Months ending December 31st, 1860.

Name of Vessel.	Three Months ending	Number of Trips	Average Number of Tons each Trip.	Total for the 12 Months	Total as shown by General Accounts, including Coal on board.
			T. cwt. lbs.	T. cwt. lbs.	T. cwt. lbs.
Anglia	March 31 ..	66	12 13 8	2790 7 67	2772 16 0
"	June 30	58	12 4 80		
"	September 30	29	12 15 29		
"	December 31	66	13 5 32		
Cambria	March 31	28	12 17 6	377 4 56	
"	June 30	Nil	...		
"	September 30	1	17 7 0	377 4 56	409 7 0
Scotia	March 31	60	14 9 102	3155 18 43	3185 9 0
"	June 30	79	13 19 6		
"	September 30	48	13 15 46		
"	December 31	38	13 15 28		
Telegraph	March 31	Nil		2037 0 86	2083 1 0
"	June 30	17	14 19 9		
"	September 30	79	13 11 91		
"	December 31	50	14 3 71		
Cambria .	December 31	29	12 11 61	364 12 23	400 9 0
Hibernia	March 31	56	15 0 66	4176 14 86	4106 5 0
"	June 30	76	14 9 22		
"	September 30 ...	78	14 8 91		
"	December 31 ...	73	15 4 46		
Hercules	March 31	33	9 6 74	1049 16 70	1038 14 0
"	June 30	23	8 17 60		
"	September 30	26	8 5 70		
"	December 31	37	8 14 28		
Ocean	March 31	40	11 9 81	500 11 104	499 5 0
"	June 30	4	10 5 84		
Sea Nymph	March 31 .	54	11 15 58	2909 18 104	2043 10 0
"	June 30	78	10 19 53		
"	September 30	78	11 4 72		
"	December 31	49	12 5 14		
..		.	...	17,422 3 69	17,438 16 0

TABLE 8.—CITY OF DUBLIN STEAM PACKET COMPANY

A Return of the Average Time of Passage and Consumption of Coal of the Mail Steamers for Six Months Ending June 30th, 1860.

Vessels.	Date.	Number of Trips.	Passages: Longest.	Passages: Shortest.	Passages: Average.	Coals consumed per Trip, including getting up Steam, and while lying at Holyhead.	Engines: Diameter of Cylinder	Engines: Length of Stroke	Engines: Nominal Horse Power
			h. m.	h. m.	h. m. s.	T. cwt. lbs.	in.	ft. in.	
Prince Arthur	January 1st to March 31st ..	120	8 45	4 8	4 43 4	11 8 0	66	4 6	220
"	April 1st to June 30th	120	6 41	4 10	4 34 0	11 0 3			
		240			4 38 7	11 4 1½			
Llewellyn ...	January 1st to March 31st	94	6 20	4 16	4 43 0	15 2 38	68	6 0	350
"	April 1st to June 30th .	120	6 17	4 19	4 42 4	14 14 37			
		214			4 42 7	14 18 37½			
Eblana	January 1st to March 31st	118	9 10	4 16	4 52 6	11 9 94	63	6 0	355
"	April 1st to June 30th	124	5 53	4 19	4 40 0	10 5 72			
		242			4 46 1	10 17 83			
St. Columba	January 1st to 31st .. . Did not carry the Mails after Jan	32	6 52	4 27	5 10 0	15 13 4	72	5 0	350

TABLE 9.—CITY OF DUBLIN STEAM PACKET COMPANY.

A Return of the Average Time of Passages and Consumption of Coal of the Mail Steamers for Three Months, ending 30th September, 1860.

Vessels.	Date.	Number of Trips.	Passages: Longest.	Passages: Shortest	Passages: Average.	Coal Consumed per Trip, including getting up Steam, and while lying up at Holyhead.	Engines: Diameter of Cylinder	Engines: Length of Stroke	Engines: Nominal Horse Power
			Fog. h. m.	h. m.	h. m.	Tons. cwt. lbs.	Inches	ft. in.	
Prince Arthur	July, August, and September .	105	6 33	4 10	4 33	11 3 5	56	4 6	220
Llewellyn ..	" " " .	89	5 33	4 16	4 41	14 0 0	68	6 0	350
Eblana	" " " .	124	6 52	4 19	4 50	10 6 50	69	6 0	355
Leinster	" " " .	34	4 25	3 21	3 31	36 6 0	98	6 6	750
Ulster	" " "	16	3 45	3 18	3 32	37 0 0	96	7 0	750

TABLE I.—RETURN OF PERFORMANCE OF HER MAJESTY'S VESSELS, FURNISHED BY THE AD[MIRALTY]

Name of Vessel	Date	Place	Time occupied	Wind	Ind. H.P. with Dynamometer	Revolutions of Propeller	Measured Speed per hour	Average Speed per hour	Length	Kind of Engine
[illegible]	May 4, 1859	Outside Breakwater, Keyham	See Remarks	6 to 7	1136	40	With & agst tide, Not ascertained	See r[emarks]	230 0	Direct Horizontal
[illegible]	September 1[illegible], 1858	Ditto		Not recorded	1480	11	"		180 0	Direct
	September 1[illegible], 1858	Ditto		"	480	13	"		181 0	Ditto
[illegible]	March [illegible], 1858	Between Sheerness and Nore Light	6 hours	"	1-1124	20	11·593	10·88	175 0	Side Lever
[illegible]	August 6, 1858	Between Sheerness and Mouse Light		"	See remarks	14	8·012	7·7[illegible]	175 0	Ditto
Centaur	October 2[illegible], 1857	Outside Breakwater, Keyham		"	954	16	Not ascertained		200 0	Direct
[illegible] with common screw	January [illegible]	Long Reach		"	301·6	72	8·100	7·30	17[illegible]	Vertical Oscillating
[illegible] with [illegible] screw	[illegible]	Lower Hope		"	1[illegible]7[illegible]	84	1[illegible]	9·2	17[illegible]	Ditto
D[illegible] with common screw	April 16, 1858	Stokes Bay	6 runs	Nearly calm	2078·[illegible]	57·33	13·822	1[illegible]·[illegible]0	240 0	Horizontal
" [illegible]	October [illegible], 1857	Ditto	[illegible] runs	No. [illegible] ahead	2[illegible]1·12	48·60	13·308	11·053	240 0	Ditto
"	October 21, 1857	Ditto	4 runs	Nearly calm	2325·06	48·75	13·124	11·601	240 0	Ditto
"	November 7, 1857	Ditto	6 runs	Calm	2[illegible]65·0	51·81	13·535	11·7[illegible]	240 0	Ditto
"	December 1, 1857	Ditto	4 runs	No. 2 on [illegible] bow course	2[illegible]87·5	[illegible]16·5	14·717	12·062	240 0	Ditto
	January [illegible], 1858	Ditto	6 runs	No. [illegible]	2[illegible]8·4	65·[illegible]5	13·702	11·808	240 0	Ditto
[illegible]	March 23, 1859	Ditto	4 runs	No. 2 to 3 variable	4011	[illegible]·25	15·106	13·290	300 0	Ditto
[illegible]	April 9, 1857	Lower Hope		Not recorded	29[illegible]·1	178	10·700	9·30	125 0	Horizontal High Pressure
"	April 29, 1857	Ditto		"	229·5	176	10·675	9·270	125 0	Ditto
"	April 13, 1857	Ditto		"	303·0	1[illegible]4	10·675	9·270	125 0	Ditto
"	[illegible]	D[itto]		"	229·8	1[illegible]	10·767	9·450	125 0	Ditto
[illegible]	[illegible] 1857	Stoke Bay	6 runs	No. 3	1009·88	71	12·429	10·731	200 0	Horizontal
" (ditto [illegible])	July 2, 1857	Ditto	6 runs	No. 2 on a [illegible]	1[illegible]63·4	77·75	12·695	11·025	200 0	Ditto
" (ditto with 1 blade instead of 2 fore & aft)	July 6, 1857	Ditto	6 runs	No. 5 [illegible]	1260·0	101	12·501	10·908	200 0	Ditto
" (ditto (ditto))	July 9, 1857	Ditto	6 runs	No. 3 [illegible]	1174·89	80	12·710	11·049	200 0	Ditto
" (with common screw)	June 10, 1857	Ditto	6 runs	No. 1 [illegible]	1[illegible]15·18	70	12·284	11·[illegible]50	200 0	Ditto
" (ditto)	May 21, 1858	Spithead		See remarks	1181·72	82	See remarks		200 0	Ditto
M[illegible]	June 2, 1856	Stoke Bay	6 runs	No. 2 to 3 up course	3054·26	54·61	12·017	11·217	215 0	Ditto
[illegible]	[illegible]	Ditto	6 runs	Ditto on a bow	2730·01	50	12·235	10·625	215 0	Ditto
[illegible]	[illegible]	Outside Breakwater, Keyham	Not recorded	No. 4 on bow and quarter	3602	53	15·154	13·16	300 0	Ditto
[illegible]	July [illegible], 1859	Stoke Bay	6 runs	No. 2 on port bow up course	190·82	110	9·296	8·071	100 0	Double Trunk
" [illegible]	March 8, 1860	Ditto	4 runs	No. 1 on a bow [illegible]	240·0	170·0	9·047	7·240	100 0	Double Trunk High Pressure
"	July 1, 1850	Ditto	6 runs	No. 1 on p. bow [illegible]	220·15	174·5	9·2	7·080	100 0	Ditto
[illegible]	October 11, 1859	Ditto	4 runs	No. 3 to 4 on p. b. up course	240·0	211	9·[illegible]20	8·015	100 0	Ditto
[illegible]	June 26, 1857	Ditto	6 runs	Calm	240·02	191·5	9·710	8·152	100 0	Ditto
[illegible]	September 10, 1857	Ditto	6 runs	No. 2 on port bow up course	[illegible]2·17	175	8·57	7·442	100 0	Ditto
[illegible]	March 20, 1858	Ditto	6 runs	Calm	241·49	1[illegible]1	9·827	8·534	100 0	Ditto
[illegible] (with enlarged screw 37 dia. 4 corners cut off)	May 23, 1859	Ditto	6 runs	No. 2 on port bow up course	29[illegible]0·72	51·813	14·032	12·012	240 0	Double Trunk
" (common screw)	April 21, 1859	Ditto	4 runs	No. 3 directly ahead	2[illegible]21·2	51·25	13·614	11·821	240 0	Ditto
" (enlarged screw 37 dia. with 2 corners cut off)	May 9, 1859	Ditto	6 runs	No. 3 on port bow up course	2881·4	50	13·874	12·048	240 0	Ditto
" (Griffith's screw)	May 27, 1859	Ditto	6 runs	No. 2 to 3 on p. b. up course	3001·1	58·25	14·124	12·[illegible]6	240 0	Ditto
" (common screw enlarged to 37)	May 6, 1859	Ditto	6 runs	No. 3 on a bow down course	2788·1	48·25	17·018	11·920	240 0	Ditto
" (or [illegible] screw)	May 26, 1859	Ditto	6 runs	No. 2 to 3 directly ahead down course	2825·0	49·833	13·706	11·981	240 0	Ditto
" (ditto)	June 3, 1859	Ditto	6 runs	No. 1 to 2 ahead down course	3000·03	53·71	14	12·158	240 0	Ditto
	[illegible] 1857	Sheerness and S[illegible]	6 hours	Not recorded	2901·75	54	12·528	1[illegible]·88*	244 0	Ditto
	[illegible]	[Sheer]ness and Sunk Light	6 hours	"	2750·[illegible]26	52·125	12·528	10·85*	244 0	Ditto
	[illegible] 1857	[Sheer]ness and Swin middle	5 hours under weigh	Fresh breeze, 1 hr before, 1 hr against	2817·3500	51·5	14·607	12·05*	244 0	Ditto
	October [illegible], 1857	Down the Swin	2 hours	"	2704	54	14·507	12·06*	244 0	Ditto
	March 15, 1858	Stokes Bay	6 runs	No. 3 to 4 ahead down, [illegible]	2751·01	51·5	13·102	11·43	244 0	Ditto
" (half boiler power)	March 16, 1859	Ditto	4 runs	No. 4 slightly on p. b. down	1820	44·5	10·531	9·115	244 0	Ditto
"	April 19, 1858	Ditto	6 runs	Nearly calm	3182·0	56·5	12·006	11·816	244 0	Ditto

*Patent L[og].

BOILERS

Ref.	Total Weight of Engines	Power (Per I.H.P.)	Power (Nominal)	Temperature of Feed Water	[illegible]	Number of Revolutions	Pressure of Steam	Vacuum	Pressure in Boiler	Pressure from Vacuum	Pressure in Cylinder	Number of Cylinders	Description of Boilers	Length	Breadth	Height	Total Weight of Boilers with Water	Total Weight of Boilers without Water	[illegible]	[illegible]	No. of Furnaces	Grate	Tube	Other	[illegible]	[illegible]	Distance of Fire Bars (ft. in. ft. in.)	Distance of Fire Bars from Tube (ft. in. ft. in.)	Area	Tubes	[illegible]	[illegible]	Material	Number and Dimensions of Chimneys	[illegible]	[illegible]	Remarks
	Tons [illegible]	2·5	40	[illegible]	[illegible]	[illegible]	15½	9½	18·8	1·5	1·4	4	Common tubular	11 4	11 0	12 10	[illegible]	11·0	[illegible]	2150	20	100	87·5	1877	4·2	703	2 8 1 2	1 3 2 0	1·8	Tubes	2·90	0 2½	Brass	One 63' 0" high, 7' 6" dia.	10	No [illegible]	Speed not ascertained, in consequence of the bad state of the weather.
	9	11·5	41	"		300	1¼	27	18·4	1·5	4½	2	"	17 10	9 0	10 3	122·5	7·1	[illegible]	155·5	11	156	3418	667	·476	730	2 8 1 8	0 9 1 4	4·7	"	·378	0 0 2½	"	One 34' [illegible] high, 6' 0" dia.	11	"	Trial for special purposes, not for speed.
	50	13	13	"		300	11	26	18·4	1·10	10	2	"	17	9 0	11 0	122·5	7·1	0·6	122·5	11	156	3158	667	·477	[illegible]	2 8 1 8	0 9 1 4	4	"	·378	0 2½	"	" "	11	"	Ditto.
	14·6	[illegible]	2	"		250	7½	27	17·08	1·2	7½	2	Cylindrical [illegible]	[illegible]	9 11	[illegible]	56	[illegible]	[illegible]	971	10	117·77	[illegible]	125	251·2	[illegible]	1 7 1 2	1 1 1 6	1·8	"	7·0	5 1 [illegible]	"	One 35' [illegible] high, 3' 6" dia.	8	"	Trial interrupted; speed not to be relied upon.
	147·6	1·4	14	"		250 and [illegible]		27	[illegible]	[illegible]	[illegible]	[illegible]	"	[illegible]	0 10	[illegible]	[illegible]	[illegible]	[illegible]	971	10	117·77	[illegible]	125	251·2	[illegible]	1 7 1 2	1 1 1 6	1·8	"	[illegible]	[illegible]	"	"	8	"	
	14·4	103	1	"		500	9½	25	11·2	[illegible]	[illegible]	4	Common tubular	11 0	11 0	11 2	1410	84·3	1644	2·65	10	211	6,068	640	[illegible]	45·72	2 3 1 2	1 2 2 0	[illegible]	"	1000	11 2	"	One 42' 0" [illegible] 7' 2" dia.	10	"	
	26·8	[illegible]	[illegible]		17 3	100	12	2[illegible]	[illegible]	11·33	1[illegible]	1	"	8 1	11 0	11 0	[illegible]	1 2	[illegible]	100	4	78	1,217	[illegible]	7·2	[illegible]	2 1 0	1 4 1 11	1·7	"	379	[illegible]	"	One [illegible] 10" dia.	12	"	Vessel purchased into the service. Area of midship section and displacement not known.
							12	25½	16·80	1·44	12	1	"	8 1	[illegible]	11 1	[illegible]	14·05	[illegible]	101	4	107	13,277	227	71·8	108	2 1 6	1 6 1 11	[illegible]	"	[illegible]	[illegible]	"	One 17' [illegible] high, 2' 0" dia.	12	"	
							2[illegible]	[illegible]	[illegible]	8·87	2[illegible]	6	"	13 10	11 7¼	12 7	[illegible]	1[illegible]·25	[illegible]	[illegible]	24	[illegible]	12,07[illegible]	2·65	64·12	[illegible]	1 1[illegible] 1 5	1 8 2 [illegible]	[illegible]	"	[illegible]	[illegible]	"	[illegible] 2' 7" dia.	2[illegible]		
							1[illegible]			7·29	1[illegible]	6	"	13 10	11 7¼	12 7	[illegible]	102·25	[illegible]	[illegible]	24	544	12,07[illegible]	2·[illegible]	64·12	8·7	1 10 1 5	1 8 2 0	[illegible]	"	[illegible]	0 [illegible]	"	" "	20		
	130	150	8·7	"	110 4	800	16½	21	18·64	8·81	10½	6	"	13 10	11 7¼	12 7	3[illegible]	102·5	2454·4	3220	24	544	12,07[illegible]	2·6[illegible]	64·12	867	1 10 1 5	1 8 2 0	100[illegible]	"	2·98	0 6½ 2½	"	" "	20		
	100	14·84	55·83	"	110 4	800	10	21 22	[illegible]	8·00	10	6	"	13 10	11 7¼	12 7	304[illegible]	102·5	2454·4	[illegible]	24	544	12,057·8	2·65	64·12	867	1 10 1 5	1 8 2 0	100[illegible]	"	2·98	0 6½ 2½	"	" "	20		
	100	130·4	71·[illegible]	"	110 4	800	15½	24 22½	19·5	9·50	15½	6	"	13 10	11 7¼	12 7	304·25	102·25	2454·4	3220	24	544	12,057·8	2·65	64·12	867	1 10 1 5	1 8 2 0	100·4	"	2·98	0 [illegible]	"	" "	20		
	100	14[illegible]	55·25	"	110 4	800	15½	21 25	18·78	9·50	15½	6	"	13 10	11 7	12 7	304·25	102·5	2454·4	3220	24	544	12,057·8	2·65	64·12	867	1 10 1 5	1 8 2 0	100·4	"	2·98	0 6½ 2½	"	" "	20	"	
	200	412	[illegible]	"	97 6	1100	20	[illegible]	2·71	1·00	20	8	"	11 7	11 6	12 1	3[illegible]7	203·7	300	4[illegible]	32	730	11,675	3·81	84·1	1152	2 1 1 1	1 8 2 3	1·3	"	[illegible]	0 0 2½	"	Two 54' 0" high, 7' 0" dia.	20	"	Blades of screw bolted on with flanges.
	6·25	47½	17½	"	40 6	80	60		4·62		60	3	Cylindrical tubular	16 3	4 8		27·0	14·25	131	440	3	33	1181	1·07	0·0	38	1 6 1 0	1 1 1 6	6·1	"	327	8 1 2	Iron	One 20' 4" high, 2' 2" dia.	65		
	6·25	4·8	1·6	"	40 0	80	60		4·75		60	3	"	16 3	4 8		27·0	14·25	131	440	3	33	1,184	1·07	0·6	38	1 6 1 0	1 1 1 6	6·1	"	327	8 1 2	"	" "	60		
	6·25	[illegible]	17½	"	40 0	80	60		4·20		60	3	"	16 3	4 8		27·0	14·25	131	440	3	33	1,184	1·07	0·6	38	1 6 1 0	1 1 1 6	6·1	"	327	8 1 2	"	" "	60		
	6·25	[illegible]	105	"	40 0	80	60		4·78		60	3	"	16 3	4 8		27·0	14·25	131	440	3	33	1181	1·07	0·6	38	1 6 1 0	1 1 1 6	6·1	"	327	8 1 2	"	" "	60		
	12	342	70	"	65 0	350	20	22	1·92	7·80	20	6	(Horizontal tubular)	8 0	10 0	6 2	115·6	70·0	1528	1365	18	247	6572·4	1186·6	467·7	396			15·8	"			"	Two 36' 6" high, 4' 11" dia.	20		
	19	310·78	72½	"	65 0	350	20	22	21·1	8·13	20	6	"	8 0	10 0	6 2	115·6	70·0	1528	1365	18	247	6572·4	1186·[illegible]	467·7	396	Low Boilers 2 5 1 3	Low Boilers 1 3 2 0	15·8	"	1110	Low Boilers 0 0 2½	Brass	" "	20		
	19	1·15	101	"	65 0	350	18 to 20	22	17·11	6·50	19	6	"	15 6	12 0	6 2	116·0	70·6	1528	1365	18	247	6572·4	1186·6	467·7	396			15·8	"				" "	20		
	19	4·1·5	89	"	65 0	350	18 to 20	22	18·2	6·58	19	6	"	15 6	12 0	6 2	116·6	70·0	1528	1365	18	247	6572·4	1186·6	467·7	396			15·8	"				" "	20		
	19	355·4	79	"	65 0	350	14 to 20	22	18·44	6·80	19½	6	"	11 1	10 0	11 0	116·6	70·6	1528	1365	18	247	6572·4	1186·6	467·7	396	High Boilers 1 9 1 3	High Boilers 1 3 1 9	15·8	"	210	High Boilers 0 0 2½	"	" "	20	"	Trial for special purposes, not for speed. Immersion of screw a negative quantity.
	19	300	82	"	65 0	350	17 to 20	21, 22	20·1	8·55	18½	6	"	10 3	10 0	11 0	115·8	70·0	1528	1365	18	247	6572·4	1186·6	467·7	396			15·8	"				" "	20	"	
	160	217·33	54·60	"	111 3	800	20	21 22	21·82	0·7	20	6	Common tubular	13 11	11 0	11 4	323·8	211·8	2700·8	3920	24	544	12057·6	2565	645	867	1 9 1 3	1 9 2 0	100·6	"	2808	0 6¾ 2½	"	One 70' 6" high, 8' 4" dia.	20	"	
	160	4·0	60·0	"	114 7½	800	17 to 20	20, 21	21·30	0·74	15½	6	"	13 11	11 9	11 4	323·8	211·8	2700·8	3920	24	544	12057·6	2565	645	867	1 9 1 3	1 9 2 0	100·6	"	2808	0 6¾ 2½	"	" "	20	"	
	174*	424	63·0	"	101 4	1000	11½	21½	22·0	0·47	19½	8	"	11 5	12 3	11 10	3020	228·0	3316	6740	33	683	16455	3268	897·6	1152	2 0 1 3	1 8 2 5	177·8	"	3520	0 8½ 2½	"	Two 55' 0" high, 6' 8" dia.	22	"	
	6·25*	204	159	"	38 0	60	60		30·22	...	60	3	Cylindrical tubular	13 8	4 4		23·8	13·5	127	300·5	3	33·75	976·5	87	22·5	30	1 4 1 2	0 11 1 1	8·6	"	273	0 8 2	Iron	One 21' 0" high, 1' 7" dia.	60	"	
	6·25	351	175·5	"	38 0	60	60		30·93	...	60	3	"	13 8	4 4		23·8	13·6	127	300·5	3	33·75	976·5	87	22·5	30	1 4 1 2	0 11 1 1	8·6	"	273	0 8 2	"	" "	60	"	
	6·25	310	175·5	"	38 0	60	60		30·50	...	60	3	"	13 8	4 4		23·8	13·5	127	300·5	3	33·75	975·5	87	22·5	30	1 4 1 2	0 11 1 1	8·6	"	273	0 8 2	"	" "	60	"	Immersion of screw a negative quantity.
	6·25	1·22	211	"	38 0	60	60		33	...	60	3	"	13 8	4 4		23·8	13·5	127	300·5	3	33·75	975·5	87	22·5	30	1 4 1 2	0 11 1 1	8·6	"	273	0 8 2	"	" "	65	"	
	6·25	[illegible]	171¼	"	38 0	60	60		30·30	...	60	3	"	13 8	4 4		23·8	13·5	127	300·5	3	33·75	975·5	87	22·5	30	1 4 1 2	0 11 1 1	8·6	"	273	0 8 2	"	" "	60	"	
	6·25	[illegible]	175	"	38 0	60	60		30·82	...	60	3	"	13 8	4 4		23·8	13·5	127	300·5	3	33·76	975·5	87	22·5	30	1 4 1 2	0 11 1 1	8·6	"	273	0 8 2	"	" "	60		
	6·25	[illegible]	194	"	38 0	60	60		30·12	...	60	3	"	13 8	4 4		23·8	11·5	127	300·5	3	33·76	975·5	87	22·5	30	1 4 1 2	0 11 1 1	8·6	"	273	0 8 2	"	" "	60		
	167*	114·60	51·833	"	100 3	800	20½	25½	22·0	10·35	20½	6	Common tubular	13 0	11 3	11 0	3040	172·0	2203	4030	24	544	11844	2301	618	816	2 3 1 2	1 1 2 2	138·2	"	278·4	0 6 2½	Brass	One 56' 0" high, 7' 8" dia.	20	"	
	162	1·6	53·[illegible]	"	100 3	800	19½	27½	[illegible]	1·[illegible]	[illegible]	6	"	13 0	11 3	11 0	3040	172·0	2203	4030	24	544	11844	2301	618	816	2 3 1 2	1 1 2 2	138·2	"	278·4	0 0 2½	"	" "	20	"	
	162	600	50	"	100 3	800	19½	26	[illegible]	[illegible]	[illegible]	6	"	13 0	11 3	11 0	3040	172·0	2203	4030	24	544	11844	2301	618	816	2 3 1 2	1 1 2 2	138·2	"	278·4	0 0 2½	"	" "	20	"	
	1·2	4·6	58·25	"	100 3	800	20½	25	29·73	9·61	20½	6	"	13 0	11 3	11 0	3040	172·0	2203	4030	24	544	11844	2301	618	816	2 3 1 2	1 1 2 2	138·2	"	278·4	0 6 2½	"	" "	20	"	
	162	360	46·25	"	100 3	800	20	20	22·57	10·78	20	6	"	13 0	11 3	11 0	3010	172·0	2263	1650	24	544	11844	2301	618	816	2 3 1 2	1 1 2 2	138·2	"	278·4	0 6 2½	"	" "	20	"	
18	1·2	[illegible]	[illegible]	"	100 3	800	[illegible]	[illegible]	[illegible]	1·[illegible]	[illegible]	6	"	13 0	11 3	11 0	3040	172·0	2203	4030	24	544	11844	2301	618	816	2 3 1 2	1 1 2 2	138·2	"	278·4	0 6 2½	"	" "	20	"	
18	162	129·08	63·71	"	100 3	800	20·0	25	21·88	10	20·0	6	"	13 0	11 3	11 0	3040	172·0	2203	4630	24	544	11844	2301	618	816	2 3 1 2	1 1 2 3	138·2	"	278·4	0 0 2½	"	" "	20	"	
18	163*	434	52 to 54	"	100 3	800	17½	25	21·11	9·50	17½	6	"	13 8	11 3	13 0	257·8	170·8	3502	3780	24	544	11844	2406	609	816	2 3 1 2	1 1 2 2	138·2	"	278·4	0 0 2½	"	One 61' 0" high, 7' 6" dia.	20	"	This trial not satisfactory, the three Patent Logs used differed materially from one another.
18	163	417	50 to 54½	"	100 3	800	19½	24½ to 26½	19·00	1·74	19½	6	"	13 8	11 3	13 0	257·8	170·8	3502	3780	24	544	11844	2406	609	816	2 3 1 2	1 1 2 2	138·2	"	278·4	0 0 2½	"	" "	20	"	
18	163	436	51 to 55	"	100 3	800	20	26½ to 23 to 26	20·18	9·74	20	6	"	13 8	11 3	13 0	257·8	170·8	3502	3780	24	544	11844	2406	609	816	2 3 1 2	1 1 2 2	138·2	"	278·4	0 0 2½	"	" "	20	"	The speed of this trial considered undetermined; two Patent Logs were lost, the third affected by the back water.
18	163	472	56	"	100 3	800	20	26	20·2	10·30	20	0	"	13 8	11 3	13 0	257·8	170·8	3502	3780	24	544	11844	2406	609	816	2 3 1 2	1 1 2 2	138·2	"	278·4	0 0 2½	"	" "	20	"	
18	163	436	61½	"	100 3	800	20	25½	19·74	9·0	20	0	"	13 8	11 3	13 0	257·8	170·8	3502	3780	24	544	11844	2406	609	816	2 3 1 2	1 1 2 2	138·2	"	278·4	0 0 2½	"	" "	20	"	
19	163	342	42 to 45	"	100 3	800	20	25½ to 26	12·83	8·48	20	0	"	13 8	11 3	13 0	257·8	179·8	3502	3780	24	544	11844	2406	609	810	2 3 1 2	1 1 2 2	138·2	"	278·4	0 0 2½	"	" "	20	"	
19	163	452	56½	"	100 3	800	20	25½	23	10·5	20	0	"	13 8	11 3	13 0	257·8	179·8	3503	3780	24	544	11844	2406	609	810	2 3 1 2	1 1 2 2	138·2	"	278·4	0 0 2½	"	" "	20	"	

* Includ. screw shaft.

[redacted]

TABLE ... (upper table)

Tubes: Number	Length (Ft. in.)	Diameter (inches, outside, inside)	Material	Number and Dimensions of Chimneys		REMARKS
1440	6 6	2½ 2¼	Brass	One 6' 9" dia., 53' high	20	Welsh Coals
1440	6 6	[illegible] 2¼				
1440	6 6	[illegible]				
1264	6 6	2½ 2¼	"	One 5' 6" dia., 53' 8" high	20	
210 / 1116	6 0 / 6 0	2½ 2¼	"	Two 4' 10" dia., 34' 0" high	20	Nova Scotia (very bad)
"	"	2½ 2¼	"	" "	20	Welsh (good)
	"	2½ 2¼	"	" "	20	Welsh (good)
1056	7 3½	2½ 2¼	"	One 7' 2" dia., 56' 8" high	21.0	
					20	
					12	Carrying 107 soldiers with their baggage and ... deck load of provisions for the ...

* ... the whole of the backs and tops of fire boxes, tops of furnaces, and three-quarters of tube surfa... The H. P. is taken from the mean of the cards. Having no practical means for ascerta... the relative volume of ... the mean pressure at the time the steam is cut off, is used.

TABLE ... (lower table)

No. of Furnaces	Tubes: Number	Length (Ft. in.)	Diameter (inches, outside, inside)	Material	Number and Dimensions of Chimneys	REMARKS
12	1112	5 0	3½ [illegible]	Iron	Two 5' dia.	
12	1100	5 6	3½ 3	"	Two 4' 6½" dia.; area 32.56	
6	259	6 0	4½ 4	"	One 5' dia.	Fitted with Messrs. Randolph and Elder's ... cylinder engines.
6	258	6 0	4½ 4	"	" "	Extracted from Log Book of the P. S. N. C.
12 (7+3)	1160	6 0	3½ 0	Brass	Two 5' 3" dia., 24 high	Consumption of coal per I.H.P. ...
	1160	6 0	3½ 0	"		Extracted from Log Book of the P. S. N. C.
6	259	6 0	4½ 0	Iron	One 6' 6" dia.	Fitted with Messrs. Randolph and Elder's double cylinder engines.
6	259	6 0	4½ 0	"	" "	Extracted from Log Book of the ...
12 (7+3)	1160	6 0	3½ 0	Brass	Two 5' 3" dia., 24 long	Consumption of coal per I.H.P. ...
	1160	6 0	3½ 0	"		Extracted from Log Book of the P. S. ...
12	1009	5 6	3½ 3½	Iron	One 6' 4" dia., length 26, area 31.47	Furnished by the L. & N. W. Railway ...
6				"	Two 4' dia., 24 high	Furnished by the West India Mail Com...
1	21			"	One 5' 4" dia., 24' high	Furnished by the West India M...
1	21			"		Ditto.
16	144			"	One 7' diam., area 38 sq. ft.	Furnished by M... Penn and S...
16	144			"		Ditto.
21				"		Extracted from Log Book by perm... Peninsular and Oriental Company.
21				"	One 8 feet diameter.	Furnished by Messrs. Humphrey and Tenna...
12	121			"	One 6' dia., area 20.27 sq. ft.	Furnished by Messrs. G. Rennie and Son
				"		Ditto.
10				"	One 6' 6" × 40', area 33.18	Messrs. R. Napier and Sons.
				"		Extracted from Log Book by permission of the Peninsular and Oriental Company.
10				⅜" thick	Two 58' 0" high, 6' 9" diam.	Furnished by the Peninsular and Oriental Co.
4				"	Two 6' dia.	Furnished by Thames Ship Building Compa... and from Messrs. Penn and Sons.
20	180	0 0	1½ 3½	"	One 8' dia.	Furnished by Messrs. Fawcett, Preston and ...
				"		Extracted from Log Book by ... Peninsular and Oriental Compa...
10	160			Iron	One 7' 6" dia., area 44 sq. ft.	Furnished by Messrs. G. Rennie and ...
				"		Ditto.
4	320	6 5	3½ 3	"	One 3' 10" dia., 27' 0" long, area 11.5	Furnished by Messrs. Morrison and ...
6	520	6 6	3½ 3	"	One 5' di., 34' 10" lg., 10.0 ar.	Ditto.
1	72	6 6	2 1½	"	One 15" dia., .7854 area	Ditto.
8	720	0 0	3½ 3½	"	Two 4' 0" di., 34' lgh, 15.9 ar.	Furnished by Messrs. J. and W. Dud...
1	56	7 0	3 2½	"	One 18" di., 15 lg., .255 area	Ditto.
2	100	7 0	2½ 0	"	One 3' 3" di., 49' high, 8.3 ar.	Furnished by Professor J. Macquorne Rankine ... by J. R. Napier. Engines by Messrs. N...
45	4300	5 3	2½ 2¼	"	Two 7' 6" diameter, area 44.17 sq. ft. each	Furnished by Messrs. James Watt & ...

†† 2½ apart.

‡‡ The introduction of Lamb and Summer's superheater appears to have effected an economy of 20 to 30 per cent.

§§ Sails set during trial, viz., fore and aft mainsail, main staysail, fore and aft foresail close hauled, whole area of canvas, 3530 square feet. Ascertained speed with 91 revolutions of screw per minute under steam alone, 9.0 knots. Speed with same number of revolutions, moderate breeze, ship within about 6 points of the wind, ... fore and aft foresail and mainsail, and main staysail, 10.0 knots. Experiment made on a distance of 13.06 nautical miles by Professor J. MacQ. Rankine, July 4, 1861.

Tables 3... the mea... Your ... experime... your Ass... The L... same offi... Your ... owners, ... of merch... the data ... before lo... thus obta... The t... Oriental ... Pacific S... Company ... Sons, the ... Fawcett, ... The Pe... spection, ... 'Delta, ... extracts t... Copies ... Calcutta, ... performan... (Appendix... The Lo... Committe... ordinary ... two conc... lengthene... enable th... good ves... great cap... quantities ... than here... In the ... somewhat ... ing the Tr... fitted wit... cylinder e... these cond... These r... with the ... the hull a ... A glance ... will at onc... of view ... The Lon... of the spe... regulated ... cember 31, ... are contai... regularity ... 1861.

TABLE 2.—SHOWING THE RESULT OF THE PERFORMANCE OF SOME OF HER MAJESTY'S VESSELS.

[illegible]

TABLE [illegible]—SHOWING THE RESULTS OF PERFORMANCE OF FOREIGN VESSELS IN THE MERCHANT [illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Vertical Direct Acting	40
						Ditto	45
						High Pres. Inverted Cyl.	11½
						Vertical Direct Acting	65
						Inverted Cylinder	10
						[illegible]	35
33 0 / 29 0 / at Boats	12 0	4 0	4	14 Eccentric Wheel	60 0	6 8	Oscillating	96

Tables 3 and 4. [illegible]
the measured mile [illegible]
Your Committee [illegible] experiments under [illegible] your Association, [illegible]
The Log-book, [illegible] same officers, with [illegible]
Your Committee [illegible] owners, engineers [illegible] of merchant vessels [illegible] the data in their [illegible] before long the [illegible] thus obtained be [illegible]
The thanks of [illegible] Oriental Company [illegible] Pacific Steam N[illegible] Company to M[illegible] Sons, the Thame[illegible] Fawcett, Preston [illegible]
The Peninsular [illegible] spection, and pl[illegible] 'Delta,' 'Nubia' [illegible] extracts they [illegible]
Copies of vo[illegible] Calcutta, and re[illegible] performances w[illegible] (Appendix, Tab[illegible]
The London [illegible] Committee with [illegible] ordinary work[illegible] two condition[illegible] lengthened 4 [illegible] enable the nav[illegible] good vessel [illegible] great capacity [illegible] qualities whic[illegible] than heretofor[illegible]
In the same [illegible] somewhat sim[illegible] ing the Trial [illegible] fitted with [illegible] cylinder engi[illegible] these conditio[illegible]
These retu[illegible] with the sam[illegible] the hull a co[illegible]
A glance [illegible] will at once [illegible] of view.
The Lon[illegible] of the speed [illegible] regulated co[illegible] cember 31, [illegible] are contain[illegible] regularity [illegible]

Tables 3 and 4. This is the more valuable, as the returns of seven trials on the measured mile are given with it.

Your Committee are aware that several officers are conducting a series of experiments under various conditions, which it is their intention to report to your Association, through this Committee, on their return home.

The Log-book, compiled by your Committee, is also being filled up by the same officers, with a similar object.

Your Committee have met with great success in their applications to shipowners, engineers, and builders for information respecting the sea performances of merchant vessels. In no case have they met with a refusal to supply all the data in their possession, and your Committee have reason to believe that before long the records kept on the voyages will be amplified, and the data thus obtained be published periodically by shipowners themselves.

The thanks of the Committee are especially due to the Peninsular and Oriental Company, to the London and North-Western Company, to the Pacific Steam Navigation Company, to the City of Dublin Steam Packet Company, to Messrs. Morrison and Co. of Newcastle, to Messrs. Penn and Sons, the Thames Shipbuilding Company, Messrs. R. Napier and Son, Messrs. Fawcett, Preston and Co., and Messrs. J. and W. Dudgeon.

The Peninsular and Oriental Company freely offered their books for inspection, and placed the logs of their vessels 'Candia,' 'Ceylon,' 'Columbia,' 'Delta,' 'Nubia,' and 'Pera,' in the hands of the Committee, to make any extracts they deemed useful.

Copies of voyages from Southampton to Alexandria, and from Aden to Calcutta, and return of those vessels respectively, were taken, and the average performances worked out. They are given in the Table of Merchant Vessels (Appendix, Table 5).

The London and North-Western Railway Company have furnished your Committee with information of especial value, viz., the trial performance and ordinary working performance of one of their vessels, the 'Cambria,' under two conditions—the first as originally constructed, the second after being lengthened 40 feet. Data of this description are precisely those required to enable the naval architect to judge what are the qualities which constitute a good vessel, and assist him in designing vessels possessed of high speed, great capacity, limited draught of water, economy of power, and all the qualities which constitute good sea-going ships, with much greater certainty than heretofore.

In the same table (No. 5) your Committee have thought fit to repeat a somewhat similar return, given in their last Report, viz., a Table, &c., showing the Trial Performance of the steam vessels 'Lima' and 'Bogota' when fitted with single-cylinder engines, and after being refitted with double-cylinder engines; also the sea performances of the same vessels under both these conditions of machinery, and on the same sea-service.

These returns, therefore, show the difference of performance of a vessel with the same machinery but lengthened in her hull, and of two vessels with the hull a constant, but with entirely different engines.

A glance at the column showing the consumption of coals in each case will at once demonstrate the importance of the subject in a commercial point of view.

The London and North-Western Company have likewise furnished returns of the speed and consumption of coal of their express and cargo boats, under regulated conditions of time, pressure, and expansion, from January 1 to December 31, 1860 (Appendix, Table 6). Similar returns for 1858 and 1859 are contained in the two former Reports of this Committee, and show the regularity with which the service has been conducted.

Your Committee would again call the attention of shipowners to the system of trials which has resulted in the combination of perfect regularity and efficiency of service with economy (so far as the vessels and machinery would admit) which this series of returns exhibits.

In the first Report of this Committee, presented to your Association at the Meeting held in Aberdeen, a series of tables are given, showing the method which was adopted for ascertaining the working capabilities of each vessel. The following explanation was furnished by Admiral Moorsom, and illustrates the means by which the proper service to be obtained from a vessel may be estimated* :—

"When the four passenger vessels, 'Anglia,' 'Cambria,' 'Hibernia,' and 'Scotia,' were first employed in August 1848, the commanders were authorized to drive them as hard as they could, subject only to the injunction not to incur danger."

After some months' trial the qualities of each vessel and her engines were ascertained, and a system was brought into operation which continues to the present time. (Tables 3–14.)

The Returns Nos. 2 and 6 show the results of the *hard driving* and the commencement of *the system* periods. The column indicating "Time," "Pressure," and "Expansion," is the key to the columns "Average Time of Passage," "Weight on Safety Valves," and "Proportion of Steam in Cylinder," and, as a sequence, also to the consumption of coal.

"Time a minimum" shows the *hard driving*. "Time a constant" shows *the system*. The relations of "pressure" and "expansion" show how, under *hard driving*, the highest pressure and the full cylinder produced the highest speed the wind and tide admitted, or how, the time being a constant, those two elements were varied at the discretion of the commander, within prescribed limits, to meet the conditions of wind and tide.

The result of the *system* on the coal is a decreasing consumption.

The Return No. 1 shows the results of certain trials under favourable conditions, but in the performance of the daily passage by four of the vessels, which results are used as the standard tests with which the results of each quarter's returns are compared.

For example, the 'Scotia' at 15·9 statute miles an hour consumes 6840 lbs. of coal as a standard. (See Table 4.)

In the Return No. 3, at the speed of 12·96 miles she consumed 5226 lbs.; the first at the rate of 430 lbs. per mile (see Table 5), and the second at about 403.

Again, in the succeeding quarter, the 'Scotia' consumed 7528 lbs. at 14·65 miles an hour, or more than 513 lbs. per mile.

Here was a case for inquiry and explanation. It will be observed that in Return No. 1 the consumption of the 'Scotia' at ordinary work at sea is 5820 lbs. per hour, and it is only when the consumption exceeds 6840 lbs. that it becomes a subject of question, the difference between those figures being allowed for contingencies.

No. 4 (see Tables 12, 13) is a Return which shows the difference between the issues of coal each half year, and the aggregate of the returns of consumption, the object of which needs no elucidation.

No. 5 (see Table 14) shows the duration of the boilers, with particulars of the work done. The saving in money under the return system, as compared with hard driving, was of course very considerable, and the latter was only justifiable as a necessary means of learning the qualities of each vessel, to be afterwards redeemed by the economy of *the system*.

The 'Hibernia,' it will be seen, was unequal to the service; and I may

* See Volume of Transactions of the Aberdeen Meeting, 1859, page 276.

here observe that experience has shown me that in machinery, as in animal power, it is essential that it should be considerably above its ordinary work.

The want of this extra power was a defect of the early locomotive engines, whose cost of working per mile was very considerably higher than that of the engines now in use.

This defect, which is that of boiler-power, prevails largely in steam-vessels, and especially in the Queen's ships.

It would be easy to show how system *must* tend to economy; and the saving of coal is apparent from the returns, and of course all the engine stores are commensurate.

But the repairs—the wear and tear—involve a much more important element of economy than even a reduced consumption of coal.

The Return for 1860 is accompanied by a check account of the consumption of coal. (Appendix, Table 7.)

The City of Dublin Steam Packet Company have obligingly furnished returns of the consumption of coal and average time of passages of their mail boats 'Prince Arthur,' 'Llewellyn,' 'Eblana,' and 'St. Columba,' from January 1st to December 30th, 1860, the last quarter embracing the fast vessels 'Leinster' and 'Ulster.' (Appendix, Tables 8 and 9.)

Your Committee were invited to attend a trial of the latter vessels between Holyhead and Kingstown, and a deputation, consisting of Admiral Moorsom, the Duke of Sutherland, Lord Alfred Paget, Mr. Wm. Smith, C.E., Mr. J. E. McConnell, and Mr. H. Wright, attended. They were kindly assisted by Mr. Watson, the Managing Director of the Company, in obtaining information connected with these vessels and their performances. The particulars of these trials will be found in Appendix, Table 5.

A deputation from your Committee, consisting of Mr. W. Smith and Mr. Wright, also at the invitation of the London and North-Western Railway Company, attended the trial of the 'Admiral Moorsom,' a new cargo boat built expressly for the conveyance of live stock. The particulars are given in Appendix, Table 5, to which your Committee would direct attention, as the speed obtained, and the steadiness exhibited by the vessel in a very heavy sea, excited considerable surprise. They have received numerous invitations from other companies and shipowners to attend the trials of their vessels.

Your Committee have been in correspondence with the Imperial naval authorities of France and of the United States.

The latter have already published various trials conducted with admirable skill and precision, and embracing most of the particulars asked for by the Committee.

In France, the Company of the Messageries Impériales have for some time given annual averages of the results of the navigation of the vessels in their service, for private use only; but on the application of your Committee to be supplied with such returns, copies were at once forwarded, with a letter from the President stating that, although it was not the usual custom of private companies to make public the information requested, and although the Report transmitted to them (the Committee's 2nd Report) contained no analogous comparison of the state of the great English companies who perform similar service, nevertheless they have not hesitated to accede to the Committee's wish, by contributing as much as lay in their power,—thus proving their cordial sympathy with the useful object the British Association have in view.

The Tables of Results of their vessels, 50 in number, for the years 1859 and 1860, are given in Appendix, Tables 10 and 11, constituting, with the one given in the last Report, a valuable series extending over three consecutive years.

Your Committee take this opportunity of expressing their satisfaction in being able to report, that since the commencement of their labours in 1857, the interest that has been taken in Steamship Performance, and the desire to assist the Association in eliciting information on the subject, not only by officers of the Royal Navy, but also of the merchant service, fully bear out the opinion expressed at the meeting of the Association in Dublin, that this subject was second to none in importance, and that its steady pursuit would tend very materially to the advancement of the science of shipbuilding and marine engineering.

The following is a general summary of the results of the Committee's labours during the past season. They have obtained—

1. The particulars of the machinery and hulls of seventeen of H.M.'s vessels, and the details of 58 trials made during the years 1857, 1858, and 1859, supplied by the Admiralty. The Committee are in possession of copies of the diagrams taken during the trials in 1859, with notes of observed facts by the officers conducting the trials. The names of the vessels are the 'James Watt,' 'Virago,' 'Hydra,' 'Centaur,' 'Industry,' 'Diadem,' 'Mersey,' 'Algerine,' 'Leven,' 'Lee,' 'Slaney,' 'Flying Fish,' 'Marlborough,' 'Orlando,' 'Bullfinch,' 'Doris,' and 'Renown.' (Appendix, Table 1.)

2. Returns of seven of H.M.'s vessels when at sea, under various circumstances, viz., under steam alone, under sail alone, and under sail and steam combined. The names of these are the 'Colossus,' 'Chesapeake,' 'Flying Fish,' 'St. George,' 'Clio,' 'Sphinx,' and 'Victor Emmanuel.'

3. Return of the London and North-Western Railway Company's steamboat 'Cambria's' trials and ordinary performances as originally built, and after being lengthened; also of the Pacific Steam Navigation Company's vessels 'Lima' and 'Bogota,' when fitted with original and other machinery; also of the new cargo boat, the 'Admiral Moorsom.'

4. Returns of the Peninsular and Oriental Company's boats 'Colombo,' 'Candia,' 'Ceylon,' 'Delta,' 'Nubia,' and 'Pera,' when on voyages between Southampton and Alexandria, and between Suez and Bombay respectively, together with particulars of their machinery and hulls furnished by the builders and engineers.

5. Returns of the Pacific Steam Navigation Company's vessels 'Guayaquil' and 'Valparaiso,' with particulars of trials and sea voyages during 1860.

6. Returns of the trials of the vessels 'Leonidas,' 'Mavrocordato,' 'Penelope,' furnished by Messrs. Morrison and Co., and the 'Thunder' and 'Midge,' by Messrs. J. and W. Dudgeon.

7. Tables showing the Results of the Navigation of the steamboats in the service of the Messageries Impériales, during the years 1859 and 1860.

8. Returns of the London and North-Western Company's steamboats 'Anglia,' 'Cambria,' 'Scotia,' 'Telegraph,' 'Hibernia,' 'Hercules,' 'Ocean,' and 'Sea Nymph,' under regulated conditions of time, pressure, and expansion, from January 1 to December 31, 1860. Half-yearly verification of the consumption of coals for the same period.

9. Return of the average time of passage and consumption of coal of the City of Dublin Steam Packet Company's mail steamers 'Prince Arthur,' 'Llewellyn,' 'Elbana,' and 'St. Columba,' for six months ending June 30th, 1860.

10. Ditto ditto, with the addition of the fast steamers 'Leinster' and 'Ulster,' for three months ending September 30th, 1860.

11. Return of the average passages of the mail packets 'Leinster,' 'Ulster,' 'Munster,' and 'Connaught,' for six months ending March 31st, 1860. (Appendix, Tables 12, 13, and 14.)

12. Return of the trial of the 'Leinster' and 'Ulster' between Holyhead and Kingstown. (Table 5.)

13. Diagrams or indicator cards* have been received, taken from the following ships:—'Cambria,' 'Admiral Moorsom,' 'Leinster' and 'Ulster,' 'Colombo' (lengthened), 'Nubia,' and 'Thunder.'

The sum of £150 voted by the Council of the Association to defray the expenses of the Committee has been expended, and the statement of the expenditure, which could not be prepared in time for publication with this Report, will be presented by the Committee at the Meeting.

The thanks of the Committee are especially due to Mr. Wm. Smith, C.E., a member of the Committee, for the large amount of assistance he has rendered in collecting information, as also by placing a room in his offices at the disposal of the Committee.

Your Committee, in conclusion, have the painful duty to record the death of their late Chairman, Admiral Moorsom, and the regret which they have felt at the melancholy event which has deprived them of their Chairman, and their sense of the great loss which has thus been sustained by your Association and by the scientific world at large, as well as by the distinguished profession to which he belonged.

(Signed) SUTHERLAND, *Chairman.*

Offices of the Committee,
19 Salisbury Street, Adelphi, London.

APPENDIX.—TABLE 12.

Return of the Average Passages of Mail Packets and Consumption of Coal for Six Months, ending 31st March, 1861.

Name of Vessel.	Number of Trips.	Average Time, including Fogs, &c.	Coal consumed, including getting up Steam.			
			Anthracite.	Bituminous.	Total.	Average per Trip.
		h m s	tons.	tons.	tons.	tons. cwt.
Leinster............	183	3 41 5	2437	3956	6393	34 13
Ulster	203	3 50 0	4244	2316	6560	32 6
Munster............	146	3 52 0	2679	2718	5397	36 5
Connaught.........	192	3 42 0	4179	2124	6303	32 16

Note.—The 'Ulster' and 'Munster' encountered a larger proportion of severe weather and fogs than the 'Leinster' and 'Connaught.'

APPENDIX.—TABLE 13.

Steam-ship 'Leinster.' On trial from Holyhead to Kingstown, April 4, 1861.

	Steam.	Barometer.	Revolutions.	Boiler Gauges.	
				Fore.	Aft.
	lbs.	inches.			
First half-hour	25	26	24	27	26½
Second "	25	26¼	23½	26½	26
Third "	24½	26¼	23½	26	25½
Fourth "	24½	26	23¾	26½	25½
Fifth "	25	26	23¾	26	25½
Sixth "	25	26	23¾	26	26
Seventh "	25	26¼	24	26½	25½

No. of Revolutions as per Counter, 4957.
Length of Passage, 3 hours 28 minutes.
Total Consumption about 49 tons.

* The indicator diagrams may be seen, by any one interested therein, by application at the Offices of the Committee.

APPENDIX.—TABLE 14.

Steam-ship 'Ulster.' On trial from Kingstown to Holyhead, April 5, 1861.

	Steam.	Revolutions.	Counter.	Vacuum.
	lbs.	per min.		
At starting	21	...	......	13¾ Steady.
First half-hour	22¾	23	702	
Second "	22½	22¾	1370	
Third "	23	23	2026	
Fourth "	23½	22¾	2716	
Fifth "	23½	23	3398	
Sixth "	22½	22½	4095	
To arrival	22	22½	4792	

Time of Passage, 3 hours 30 minutes. Total Consumption, about 36 tons.
No. of Revolutions as per Counter, 4792.

Circular referred to at page 192.

BRITISH ASSOCIATION.—COMMITTEE ON STEAM-SHIP PERFORMANCE.

19 Salisbury Street, Strand, London, W.C.
November 21st, 1860.

SIR,—Enclosed is a Form which the Steam-ship Performance Committee of the British Association hope you will kindly fill up at your convenience, and transmit to me.

The Committee have apprised the Admiralty of their intention to communicate with such Captains and Engineers of H.M. Ships as may be disposed to assist the British Association in obtaining facts for scientific calculations relating to the Performance of Ships at sea, and have, at their Lordships' request, sent them a copy of the Form.

The Form proposed is as simple as is consistent with the object of obtaining data necessary for calculation, and the Committee are under the impression that the time required to fill up such Forms cannot interfere with the duties of the respective Officers.

It is, however, to be clearly understood that it is for objects of science alone that the Officers are invited thus to aid the labours of the British Association, one of whose fundamental rules is laid down in the following terms:—

"The object of the Committee is to make public such recorded facts through the medium of the Association, and being accessible to the public in that manner, to bring the greatest amount of science to the solution of the difficulties now existing to the scientific improvement of the forms of vessels and the qualities of marine engines. They will especially endeavour to guard against information so furnished to them being used in any other way, and they trust they may look for the co-operation of Members of the Yacht Club having steam yachts, of Shipowners, as well as of Builders and Engineers."

I am, Sir, your obedient Servant,

C. R. MOORSOM, *Vice-Admiral and Chairman.*

ERRATA AND ADDENDUM IN TABLE V.

Col. 12, last line but one, for "*about* 64,700", read "*total* 64,700."
Col. 60, for "2" read "*with.*"
Col. 14 requires the following explanation:—

Actual speed	10·6	knots.
Deducted for tide	0·6	"
Speed through the water under sail and steam at 84 revolutions per minute	10·0	"
Previously ascertained speed under steam alone at 84 revolutions	9·6	"

British Association.—Committee on Steam-ship Performance.

Return of H.M.'s Steam-ship ____________________

Date, ________ *day, the* ______________ *day of* ____________ 18

Date ....
Latitude ....
Longitude ....
Ship's Course ....

Wind:—
Direction ....
Force ....
State of Sea ....

Under Sail alone:—
No. of Hours ....
Area of Sail set ....
Description of Sail set ....
Average Speed per hour ....

Under Sail and Steam combined:—
No. of Hours ....
Area of Sail set ....
Description of Sail set ....
Average Speed per hour ....

Under Steam alone:—
No. of Hours ....
Average Speed per hour ....

Engines:—
Cut-off in proportion of Stroke ....
Lap of Slide Valve ....
Average Revolutions per minute ....
Mean pressure of Steam at or near Cylinder ....
Mean pressure in Cylinder ....

Barometer:—
Vacuum ....
Pressure ....

Temperature of Sea-water ....
Slip of Screw ....

Boilers:—
No. of Furnaces at Work ....
Square Feet of Grate Surface at Work ....
Square Feet of Heating Surface at Work ....
Weight to which Safety Valve is loaded per Square Inch...
Pressure of Steam per Square Inch in Steam Chest ....
Density of Water ....
Consumption of Coal per hour ....
Description of Coal during period ....
Indicated Horse-power, *with Diagrams* ....
Evaporation of Water per hour ....

Draught of Water:—
On Leaving Port—Forward ....
Ditto ditto Aft ....
On Arriving in Port—Forward ....
Ditto ditto Aft ....

Remarks ....

Office, 19 Salisbury Street, Strand,
London, W.C.

Signature ____________________

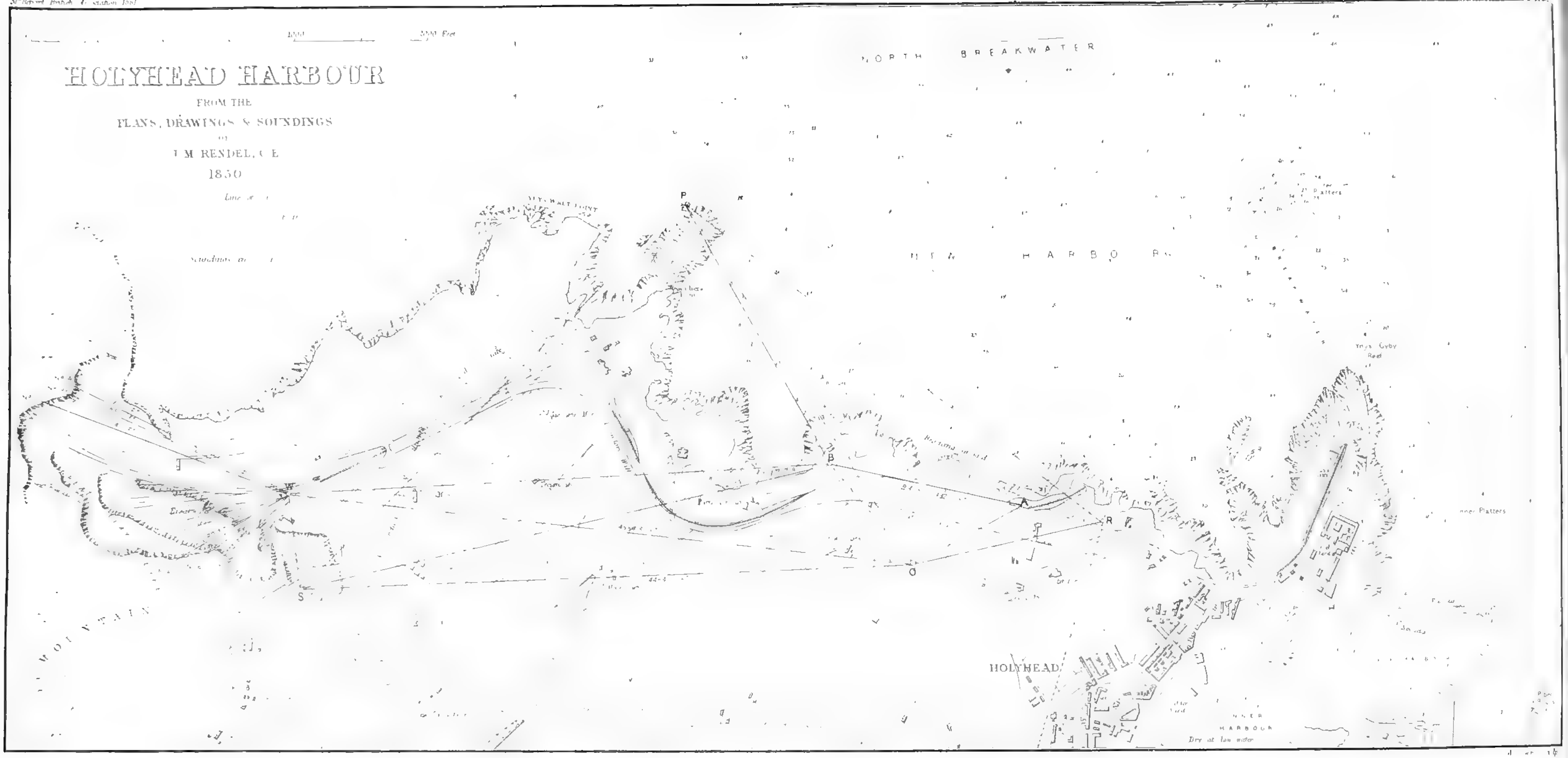
Date ____________________

Preliminary Report on the Best Mode of Preventing the Ravages of Teredo *and other Animals in our Ships and Harbours. By* J. Gwyn Jeffreys, *F.R.S., F.G.S.*

Since the last meeting, Mr. Jeffreys went to Holland for the purpose of investigating the experiments which are being made there, under the direction of the Academy of Sciences at Amsterdam, and with the sanction of the Dutch Government, in order to check the destructive ravages of the *Teredo marina*; and he was accompanied by Dr. Verloren, of Utrecht, another member of the Committee. The progress of these different experiments is periodically and carefully recorded; but it will take many years before the result can be shown. From an elaborate report of the Dutch Commission, published last year, and which was placed by M. Van der Hoeven in Mr. Jeffreys's hands, it appears that no efficacious remedy had at that time been discovered. Even the expensive process of creosoting the timber failed in one instance where the piece of wood thus treated was in contact with another piece which had not been creosoted; the *Teredo* having indiscriminately perforated both pieces of wood, first attacking the uncreosoted wood. Mr. Jeffreys had also lately seen a piece of wood used in the construction of harbour works at Scrabster, which, although it had been creosoted to the extent of 10 pounds to the square foot (having been first dressed and cut), was excavated on every side by the *Limnoria lignorum*. Iron-headed or scupper nails afford very little protection, as the *Teredo* and *Limnoria* work their way even through the rust, unless it is very thick, the valves of the *Teredo* becoming stained in consequence. The remedy suggested by Mr. Jeffreys (viz. a coating of some siliceous or mineral composition) had not been tried in Holland or France. Among other communications received by Mr. Jeffreys on the subject was one from Mr. William Hutton, of Sunderland, who had recently taken out a patent "for preventing the destruction of timber from the action of marine animals." His process is to force into the wood a soluble silex, or water glass, with muriate of lime. If this process is not expensive, it would no doubt answer the desired purpose; but it is probable that the same object would be attained by merely soaking the wood in a solution of this kind, or even laying it on the wood with a brush. It would seem to be sufficient if the outer layer of the wood were coated or glazed in such a manner that the composition would not crack or peel off.

Although the different kinds of *Teredo* are locally and partially distributed on our coasts, the wood-boring Crustacea (and especially *Limnoria lignorum*) occur everywhere in countless numbers, and on the whole do the greatest damage to our harbour works. Mr. Jeffreys endeavoured to obtain, through a member of the Committee who resided at Plymouth, permission from the Admiralty to institute some experiments in the Dockyard there, having been informed that very considerable damage had been sustained in that port during many years past from the last-mentioned cause. But, although a copy of the Association's Proceedings was furnished to the First Lord and Secretary to the Admiralty, and the Port-Admiral expressed his approval of the experiments being tried, and forwarded the application to the Admiralty, permission was refused. It does not appear that the Admiralty or Government have taken any steps to prevent further loss, or even to inquire into the matter.

Notwithstanding this discouragement, Mr. Jeffreys will persevere, with the assistance of the other members of the Committee, in doing all that is possible to ensure such an important and national object as the protection of our ships and harbours from the destructive attacks of these animals.



HOLYHEAD HARBOUR
FROM THE
PLANS, DRAWINGS & SOUNDINGS
J. M. RENDEL, C.E.
1850
2000 Feet
NORTH BREAKWATER
HARBOUR
HOLYHEAD
HARBOUR
Dry at low water

Report of the Experiments made at Holyhead (North Wales) to ascertain the Transit-Velocity of Waves, analogous to Earthquake Waves, through the local Rock Formations: by command of the Royal Society and of the British Association for the Advancement of Science. By Robert Mallet, *C.E., F.R.S.*

In my "Second Report on the Facts of Earthquake Phenomena," in the Report of the British Association for 1851, the transit-velocities were experimentally determined of waves of impulse produced by the explosion of charges of gunpowder, and these velocities shown to be—

In wet sand	824·915 feet per second,
In discontinuous granite	1306·425 feet per second,
In more solid granite	1664·574 feet per second,

the range of sand employed having been that of Killiney Strand, and of granite that of Dalkey Island, both on the east coast of Ireland. These results produced some surprise on my own part, as well as on that of others, the transit-velocities obtained falling greatly below those which theory might have suggested as possible, based upon the modulus of elasticity of the material constituting the range in either case.

I suggested as the explanation of the low velocities ascertained, that the media of the ranges (like all the solids constituting the crust of the earth) were not in fact united and homogeneous elastic solids, but an aggregation of solids more or less shattered, heterogeneous, and discontinuous; and that to the loss of *vis viva*, and of time in the propagation of the wave from surface to surface, was due the extremely low velocities observed.

The correctness of this view, and a general corroboration of the correctness of the experimental results themselves, have since been made known by the careful determinations by Nöggerath and Schmidt respectively, of the transit-velocities of actual earthquake waves in the superficial formations of the Rhine country and of Hungary, and by myself in those of Southern Italy, all of which present low velocities coordinating readily with my previous experimental results.

In the Report above mentioned, I suggested the desirableness of extending the experimental determination of wave-transit to stratified and foliated rocks, as likely to present still lower velocities than those obtained for shattered granite, as well as other important or suggestive phenomena. The operations in progress at the Government quarries at Holyhead (Island of Anglesea, North Wales), of dislodging vast masses of rock by means of gunpowder for the formation of the Asylum Harbour there, appeared to me to present a favourable opportunity of making some experiments upon the stratified rock formations of that locality, by taking advantage of the powerful explosions necessary at the quarries. These quarries are situated (see Map, Pl. II.) on Holyhead Mountain, on its N.E. flank, in metamorphic quartz rock, and in 1852 (a vast mass of material having been already removed) presented a lofty, irregular, and nearly vertical scarp, reaching to 150 feet in height above the floor of the quarry in some places.

From this wall of solid rock the process of dislodgement was continued, not by the usual method of blasting, by means of small charges fired in jumper-holes bored into the rock, but by the occasional explosion of large mines, containing at times as much as *nine tons* of gunpowder lodged in one or in three or more separate foci deep within the face of the cliff, and formed by driving "headings" or galleries from the base of the mural face into the rock. From the charges of powder placed in bags at the innermost extremities of these headings, which were stopped up by several feet of "tamping" of stone, rubbish, and clay, conducting wires were led out to a suitable and safe distance, so that on making by these the circuit complete between the poles of a powerful Smee's galvanic battery, a small piece of thin platinum wire adjusted within the charge of gunpowder became heated, and ignited the powder. The explosion thus followed instantaneously the making contact between the poles of the battery.

Experience has enabled the engineers charged with the work so exactly to proportion the charge of powder to the work it is intended to perform in each case, that no rock is thrown to any distance; the whole force is consumed in dislocating and dropping down to its base as a vast sloping talus of disrupted rock and stone the portion of the cliff operated on; in fact, at the moment of explosion the mass of previously solid rock seems to fall to pieces like a lump of suddenly slacked quicklime. The shock or impulse, however, delivered by the explosion upon the remaining solid rock, behind and around the focus, and propagated through it in all directions outwards, as an elastic wave of impulse, was at an early stage of the operations remarked to be so powerful, that it could be felt distinctly in the quaking of the ground at distances of several hundred yards, and was sufficient even to shake down articles of delf ware from the shelves of cottages a long way off from the quarries.

Early in 1853 I visited those quarries, and examined generally the adjacent locality and rock formations, and having satisfied myself that these operations could be made available, I applied to my distinguished friend, the late lamented Mr. Rendel, C.E., the engineer-in-chief of the Asylum Harbour, and readily obtained from him permission to make such experiments as should not interfere with the progress of the works.

The prosecution of these experiments having been favourably represented to the British Association for the Advancement of Science, and to the Council of the Royal Society, a sum of money was voted by each of these bodies respectively, and placed at the author's disposal, with the desire that he should undertake and conduct the experiments.

It was not, however, until the summer of 1856 that my own avocations and various preliminaries allowed any progress to be made with the experiments themselves. Negotiations had to be entered on with several parties; with the occupier of some land at Pen-y-Brin, about a mile to the east of the quarries, where the most suitable spot for placing the seismoscope (the observer's station O, see Map) was found, for permission to enter his land, and level down to a horizontal surface the face of the rock here occupying the surface of the ground, and to erect an observer's shed over it; and with the Electric Telegraph Company, for the hire of insulating telegraph poles and wires, and for their erection over the range intervening between this spot and the highest reach of the quarry hill.

As these great blasts are fired only occasionally and at uncertain intervals, and being prepared *must be fired without postponement*, and within a given hour of the day, namely, during the workmen's dinner-hour (12 to 1 P.M.), when the quarries are clear of men, and therefore safe from accident, it became at once obvious that very frequent journeys, both on my own part and on that of such assistants as I should require, would have necessarily to be made to and from Holyhead; and to economize as much as possible the large expenditure that must thus arise, I applied to the City of Dublin Steam Packet Company, and to the Chester and Holyhead Railway Company, through their respective Secretaries, representing the scientific character of the undertaking, and requesting on their parts cooperation, by their permitting myself and my assistants, with any needful apparatus, to pass free to and from Holyhead by their respective vessels from Kingstown Harbour. After much fruitless correspondence I regret to say that both these Companies refused to render any assistance whatever, a boon the refusal of which greatly increased the expenditure for these experiments. Lastly, I placed myself in communication with Messrs. Rigby, the contractors for the vast works of the Quarries and Harbour, and in August 1856 received from them the assurance of every assistance that they could afford consistently with the prosecution of the works. To them, to Mr. R. L. Cousens, C.E., the acting engineer for their firm on the works, and to Mr. G. C. Dobson, C.E., chief engineer on the work under Mr. Rendel (since under Mr. Hawkshaw), my thanks are due for the best and most cordial assistance upon all occasions.

The position for the observer's station and seismoscope upon the levelled floor of rock at Pen-y-Brin having been fixed upon, the first operation necessary was to obtain an accurate section of the surface in the line between that and the quarries, a geological section of the rock formations along the same line, and with precision the exact distance in a straight line, from some fixed point adjacent to the quarries, to the observer's station. The fixed point chosen at the quarries was the flagstaff at the bell, which is rung whenever a blast is about to be fired, this being so placed that from it measurements and angular bearings, with the line of range O W (Map), from the various sites of future explosions could readily be made, and thus the exact distance of each focus of explosion (to be hereafter experimented on) from the seismoscope at O ascertained, the flagstaff always remaining undisturbed as a fixed terminal at the quarry end of the range. The whole surface, O to W, was carefully levelled over, and the distances chained, as given in the diagram, Pl. III. section 2. fig. 1. The roughness of the ground and its inclination, however, rendered direct measurement of the range of wave-path with sufficient accuracy impracticable, and it was found necessary to obtain it trigonometrically. For this purpose a base line of 1432 feet in length was measured off along the rails of the tramroad which connects the quarry with the east breakwater, between the points A and B (Map, Pl. II.), where the road fortunately was found straight and nearly level.

This was measured with two brass-shod pine rods, each of 35 feet in length, of the same sort, and applied in the same manner, as I used in 1849 for measuring the base of one mile on Killiney Strand, for the particulars of which the "Second Report on Earthquakes," &c., Report Brit. Assoc. 1851, p. 274, &c., may be referred to. The base was measured forwards and backwards, with a result differing by less than 3 inches. The flagstaff at the spot marked W in the Map is not visible from the observer's station, owing to some intervening houses and other objects; a staff was therefore set up at S, upon the hill-side. The point O was connected by angular measurements with the extremities of the measured base A and B; the triangles OBS and OSW were then obtained, whence that OBW was arrived at, from which finally the distance OW (the constant part of the range) was ascertained to be=4584·80 feet. The triangle OBW was used as a check upon that OSW, as the angles at O, S, and W had to be taken, owing to local circumstances, smaller than is desirable. The lengths of the side OW obtained from the two triangles separately closely agreed; and as a further check, the side SW, which gave, trigonometrically, a length of 671·07 feet, when actually measured as a base of verification, gave 672·05 feet.

I was also enabled to connect the side OS with a trig-point P, upon the western breakwater, and another at R, the positions of which are defined upon the accurate surveys of the harbour in Mr. Dobson's possession, as a further means of verification. We may therefore view the length of the constant part of the range between the observing station and the flagstaff, its other permanent terminal, as equal to 4585 feet, neglecting fractions.

The base of the staff at S was found to be 68·78 feet above the level of the horizontal surface of the rock at Pen-y-Brin (the observing station O), and the base of the flagstaff at W is 5·70 feet above the same point O. The levelled surface of rock at O is 84 feet above the mean tide-level of the sea in the Asylum Harbour; and the average rise and fall of spring tides at Holyhead is 18 feet; the line of rock, therefore, through which the range passes is, except as respects surface water, permanently dry to a considerable depth. The majority of the headings are driven into the face of the quarry cliff horizontally, at from 10 to 20 feet above the level of the floor of the quarry, which is on nearly the same level as the point W. Hence, practically, the actual range of transmission through the solid rock of the impulse from each heading when fired, to the seismoscope at the observer's station, may be considered as a horizontal line, and no correction of distance is required for difference of elevation at the two extremities of the observing-range in the reduction of our results.

The Island of Holyhead, as may be seen on consulting the sheets (Nos. 77 and 78) of the Geological Survey of England and Wales, consists mainly of chloritic and micaceous schist or slate and of quartz rock. The latter forms the north-west portion of the island; and in it alone are situated the Harbour quarries, upon the side of Holyhead Mountain (as it is called), the same rock rising to its summit, which is 742 feet above the sea, mean tide-level. The junction of the quartz and of the schist or slate rock runs in azimuth N. 24° E. where it crosses the line of our range, which it intersects at an angle horizontally of 73° 30′.

The schist or slate rocks here overlie the quartz, abutting against the flank of the latter, apparently unconformably, and having an inclined junction whose dip is towards the south-east, and probably, at the place where our range intersects, having an angle of dip of about 65° with the vertical. The point of junction is situated about 900 feet from the flagstaff W; so that about 2100 feet, on the average, of our actual ranges lay in quartz rock, and the remainder, or 3750 feet, in the schist or slate formation, taking the mean total range at 5851 feet. The general tendency of the schist is to a dip to the north-west, varying from 5° to 20° from the horizontal; but no well-defined bedding is obvious either in it or in the quartz.

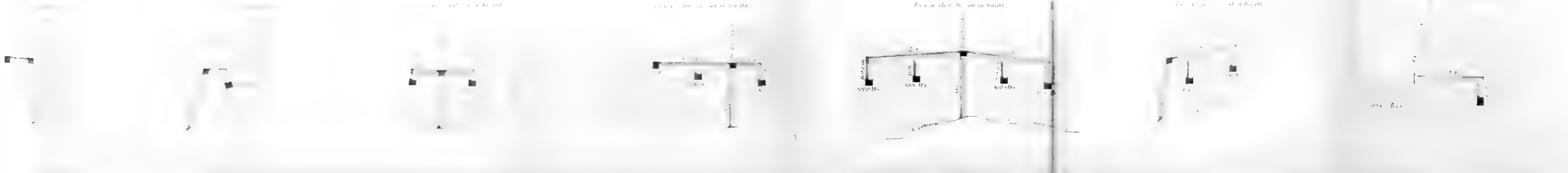
Lithologically, the quartz rock consists of very variable proportions of pure white, light grey, and yellowish quartz, and of white or yellowish-white aluminous and finally micaceous clays. In many places the mass of the rock presents to the lens almost nothing but clear and translucent quartz, breaking with a fine waved glassy fracture, striking fire with steel, extremely hard and difficult to break, and showing a very ill-defined crystallization of the individual particles of quartz, which have all the appearance of pure quartzose sea-sand that had become agglutinated by heat and pressure coacting with some slight admixture of the nature of a flux. The specific gravity of such portions, as determined for me by my friend Mr. Robert H. Scott, A.M., Secretary to the Geological Society of Dublin, is 2·656. From this the rock passes in many places into a softer and more friable material, consisting, when minutely examined, of the same sort of quartz-grains, with a white pulverulent clay, containing microscopic plates of mica disseminated between them; this fractures readily, but will still strike fire with steel, and its average specific gravity is 2·650.

Both, but particularly the harder variety, are found often in very thick masses of nearly uniform quality, separated by great master-joints, though

EARTHQUAKE EXPERIMENTS, HOLYHEAD QUARRIES. No. 2.

Section of Surface O to S of Map and Geological Section of Range

Horizontal and Vertical Sections of the several Headings Experimented upon at the Government Quarries Harbour Works Holyhead



scarcely to be considered as beds; but usually the mass, viewed in the large, is heterogeneous in the highest degree, massive and thick in one place, full of joints and even minutely foliated in others, and everywhere intersected by thin and thick veins of harder quartz, agglutinated sand, and, elsewhere, friable sand, and of soft sandy clay.

Both the quartz rock and the schist of the island are intersected by three great greenstone dykes (of inconsiderable thickness, however), none of them interfering with our range, and by one or more great faults, all of which run through nearly the whole island in a N.W. and S.E. direction, and by numerous other minor faults and dislocations, some of which may be seen as cutting through our line of range at *f, g, k, l,* in Plate III. section 2. No. 11.

At a short distance behind the quarry cliff, and seat of our several explosions, a great clay dyke occurs in the quartz rock—a wall, in fact, of about 20 feet in average thickness, running in the direction marked on the Map (Plate II.), and with a dip of only about 20° from the vertical. This consists of strongly compacted clay, nearly pure white, and more or less mixed with fine sand and grains of mica, but cannot be called rock, though continually passing into stony masses. Lying as it does in rear of our experimental headings, it was of some value, as presenting a dead solid *anvil* to the pulse from each explosion, in the contrary direction to that of the observed wave of impulse, and hence causing a larger and more distinctly appreciable wave to be transmitted in the direction towards the seismoscope.

The schist rock, in colour, passes from fawn-colour and light-greenish ashen-grey into a rather dark tea-green. It owes its colour to disseminated thin layers of chlorite, and probably of black or green mica in minute scales, between which are thicker layers of quartz, presenting identically the same mineral characters as those of the quartz rock beneath. These layers, owing to the small relative hardness and cohesion of the chlorite and mica, present planes of weakness and of separation; the rock is, in fact, everywhere thinly foliated, the average thickness of a plate seldom exceeding 0·2 of an inch, and averaging about one-half that thickness. These foliations are twisted, bent, doubled up, and distorted in every conceivable way: the contortions are often large, the curves having radii of some feet, with minor distortions within and upon them; but most commonly they are small; so that it is rare to get even a hand specimen presenting flat and undistorted foliations, while, quite commonly, hand specimens may be found presenting, within a cube of four or five inches, two or three curves of contrary flexure, often in all three axes, and with curvatures short, sharp, and abrupt, almost angular. There is a general tendency observable in the greater convolutions to conform more or less to the surface contour of the country; so that the largest and flattest folds are found to occupy, with an approach to horizontality, the topmost portions of the great humps or *umbos* of schist rock that form the characteristic of the landscape, and so rolling off in folds smaller, steeper, and more convoluted towards the steeper sides, as though these masses had slipped and doubled upon themselves when soft and pasty.

Occasionally, however, where deep cuttings have exposed the interior of such surface-knolls, it is found sharply convoluted and twisted in all directions, and without any relation to the existing surface of the country. Everywhere this mass of minutely structured, convoluted, and foliated rock is cut through by joints of separation, with surfaces in direct and close contact, and by thin seams and veins of hard and sometimes pretty well crystallized quartz, now and then discoloured by oxide of iron, and with minute cavities filled with chlorite and mica, and with others of agglutinated quartzose sand, whose bounding-lines pass off rapidly, but *gradatim*, into the prevailing substance of the rock. It is by no means of equal hardness; some portions (and these occur without any order or traceable relationship throughout the mass) are much thinner in the foliation, and the layers of chlorite and mica nearly as thick as those of the intervening quartz, both being so attenuated, that to the naked eye the edge of the foliation presents only a fine streaky appearance of lighter and darker green-grey tint. The softest, however, readily strikes fire with steel, and throughout the whole mass of the rock (for the length of our range) it is so hard, coherent, and intractable as to be only capable of being quarried by the aid of gunpowder, and with very closely formed jumper-holes.

The specific gravity of the densest portions of the schist rock reaches 2·765; that of the softer averages 2·746. When the rock, whether hard or soft, is broken so that the applied surfaces of the foliations are visible, they are often found glistening and greasy to the feel, from flattened microscopic scales of mica, or possibly of talc.

The quartz rock fractures under the effect of gunpowder into great lumpy masses, with much small rubbish; the schist under that, from jumper-hole blasts, breaks up into coarse, angular, knotted, and most irregular wedges, the foliations breaking across in irregularly receding steps, and (throughout our range at least) a stone with a single flat bed being perhaps unprocurable. Both rocks are absolutely dry, or free from all perceptible percolations of surface-water issuing as springs, nor does the rain penetrate their substance by absorption for any appreciable depth,—both indications of their generally compact structure.

The faults with which our range is intersected, in four places, at a horizontal angle of about 75°, are not far from vertical, dipping a few degrees to the N.W. They occur at the points marked *f*, *g*, *k*, *l*, on the Geological Section (Plate III. section 2); and the disturbed and shattered plate of rock between each pair respectively appears to have sustained a downthrow (or the rocks at either side the contrary) of a few feet, 10 to 12 probably. The surfaces of the walls of these faults, so far as I can judge from rather imperfect superficial indications, appear to be in close contact; and such is the character of all the small faults that intersect the formation hereabouts.

I have been thus tediously minute in describing the character of the rocks throughout our range, because, if experimental determinations of earth-wave transit are to become useful elements of comparison in the hands of the seismologists of other countries with the observed transit-times of natural earthquake-waves, and a means of controlling such observations, it is essential that the means be afforded of accurately comparing the rock-formation traversed in both cases.

From what has been described, it will be remarked that the rock here chosen for experiment presents in the highest degree the properties capable of producing dispersion, delay, and rapid extinction of the wave of impulse, so far as its structure is concerned, although the modulus of elasticity of a very large proportion of its mineral constituents (silex) is extremely high, and its specific gravity as great as that of Dalkey granite. Added to its minutely foliated and mineralogically heterogeneous character, with its multiplied convolutions, we have five great planes of transverse separation in the range, one of these forming the plane of junction of the quartz and schist, with innumerable minor planes of separation at all conceivable angles to each other in both rocks; and yet we have highly elastic and dense materials forming the substance of both rocks, and their general mass remarkably free from open veins, fissures, or cavities.

We have also two different rocks, the one transmitting the impulse into the other, yet neither so widely differing from the other in molecular and other physical characters as to make any great or abrupt effect upon the wave at the junction probable. In fact, widely, to the first glance, as the quartz rock and the schist rock appear to differ, there is less real distinction of physical character between them than would be supposed: both are composed of the same siliceous sand in about the same size of original grains, variously enveloped, in the one in chlorite and mica, and in the other in white or grey clay and mica; both have, in ancient geological epochs, doubtless derived their materials by degradation and transport from a common source, as respects their main constituent, the silex; both have been submitted to approximately similar pressures, and probably like temperatures; and the agglutinating flux has probably been mainly the same for both, viz. the minute proportions of alkalies derived from the waters of an ancient ocean. The main difference in physical structure, viewed upon the broad scale, between the quartz rock and the slate is this (as regards our experiments):—that the great joints and planes of separation on the whole approximate to *verticality* in the former, while in the latter, with the exception of some larger faults and dykes, the planes of separation are twisted and involved in all directions, but tend more to approach *horizontality*.

More interesting conditions could thus scarcely be found for experimental determination of the transit-rate of earth-waves, or more desirable for future comparison with that of earthquake-waves themselves; much more instructive, indeed, were the actual conditions than if the means of experiment presented by these vast quarry operations had been in the most regular, undisturbed, and horizontal stratified rock, like some of the mountain limestone of Ireland, or the finest and densest laminated roofing-slates of Wales. In such ranges we can predict that the transit-velocity would at least be high. In the medium chosen for these experiments it was impossible even to guess what it might be found.

I proceed to describe the instrumental arrangements made for the observation of the impulse-wave transmitted from the blasts chosen, and for the determination of the transit-time along the range of wave-path. Over the surface of solid rock that had been chiselled down to a level tabular surface at (O) Pen-y-Brin, a timber-shed was erected, of sufficient size to place the observer, an assistant, and all the instruments proper to that spot, under cover and secured from the wind. The side to the N.W. was open, to permit of observation along the line of range, with the means of partially closing it in high winds.

Along the line of the boundary-wall of the railway next Pen-y-Brin, and thence along up to the highest and most distant point of the quarry cliffs, a line of telegraph-posts was planted, and upon these two properly insulated iron wires were hung, in such a manner that at any point along their length over the quarry cliffs, a pair of branch wires (covered with gutta percha) could be led off, and in like manner another pair to the apparatus in the observing-shed at Pen-y-Brin, thus giving the means of galvanically connecting the extremities of the range in any way that might be required.

The mines in use at the quarries frequently consist of two, three, or four separate chambers and charges, which are all fired simultaneously (see Pl. IV.); but each charge is fired by a distinct pair of wires, igniting a fine platinum wire interposed in the circuit and immersed in one of the powder-bags. The arrangement of this platinum wire in its hollow wooden frame to prevent disturbance, and its connexion with the large conducting wires, are practically the same as those adopted by me in 1849 at Killiney, and will be found fully described in "Second Report on Earthquakes," &c., Report of British Association for 1851, p. 277.

When several charges are to be fired simultaneously, all the electro-positive wires from each chamber are collected into one mercury-cup in connexion with one pole of the battery, and all the electro-negative wires into another mercury-cup. Upon making contact between the latter and the second pole of the battery, the current at the same moment ignites all the platinum wires passing through each pair of wires as a separate conducting path. This method requires considerable battery power, but is the only certain or reliable one for firing simultaneously a number of separate charges. When an attempt is made to pass the current from one pole of the battery through a single pair of wires, and through all the fine platinum priming wires in succession to the return pole, there is extreme risk that the first or second platinum priming, owing to its attenuated section of wire (in virtue of which indeed alone it becomes ignited at all), may interpose so much resistance to the current as to prevent the ignition of the third, or fourth, or other subsequent primings, or that the first priming-wire may get absolutely fused or broken by the first-ignited powder, and so cut off all communication with the others before they have been heated sufficiently.

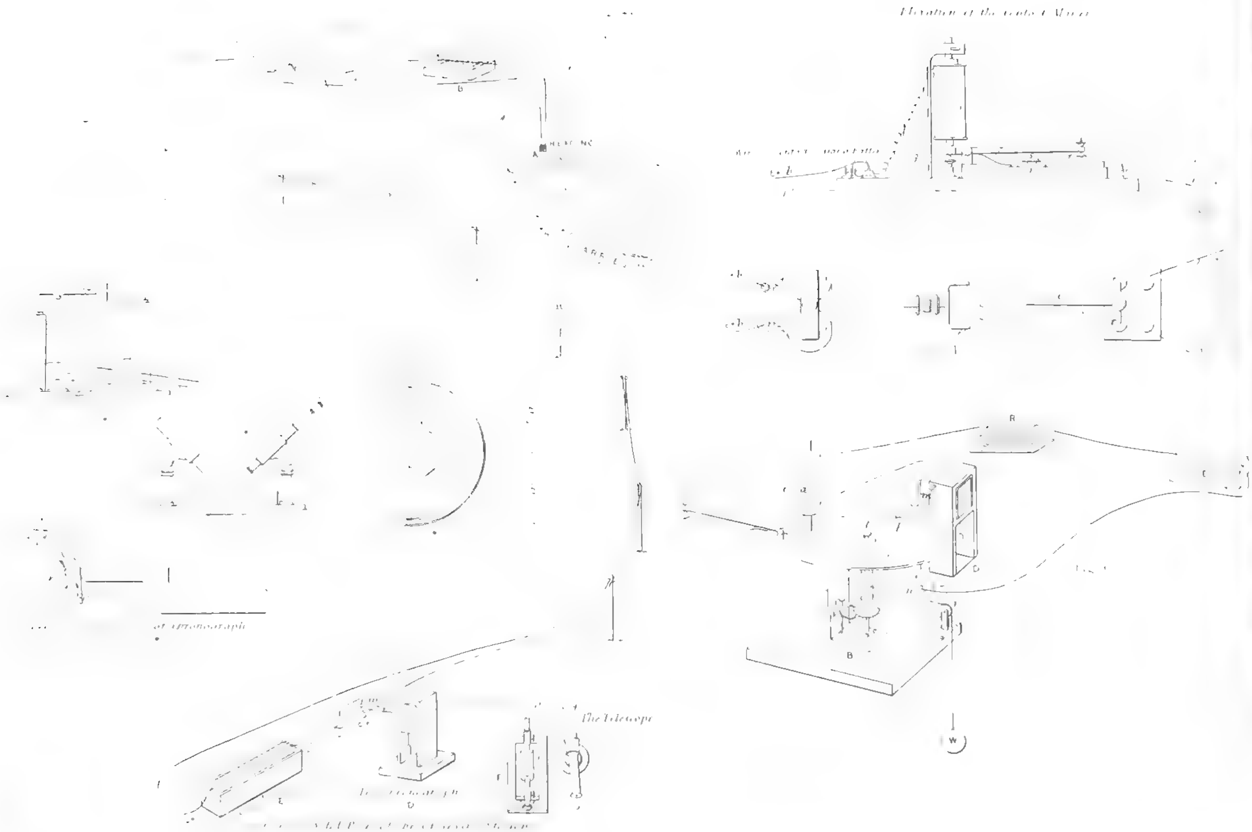
A neglect of this obvious consequence of Ohm's law of resistance appears to have been the cause of failure very recently, in an attempt to ignite a number of mines of demolition simultaneously, at Chatham. From the great magnitude of the charges frequently fired at Holyhead, and the very serious consequences that failure of ignition would involve, the battery power habitually employed is wisely of superabundant power. It consists of a Grove's battery of thirty-two cells, each exposing ninety-six square inches of platinum element. It is but justice to my friend Mr. R. L. Cousens, C.E., to whose assistance in these experiments I am so much indebted, to add, that during the several years he has controlled these vast blasting-operations a single failure of ignition has never occurred.

For the above reasons, and from the necessity that in the event of any failure of such apparatus as I might require for experiment, in making contact and firing the mine at a given moment, the power should still be reserved to Mr. Cousins to fire it directly afterwards in the usual way, so as not to interfere with the works, I was led, finally, to devise the following magneto-galvanic arrangement, by which, at a signal given from the summit of the quarry cliff (where the firing-battery is usually placed, nearly above the mine or heading then to be fired, and at a safe distance back from the edge of the cliff, usually about 100 yards) that all was ready, I should myself, stationed at the observing-shed (O), be enabled to complete the contact and fire the mine, and do so in such a way as to register by means of the chronograph the interval of time that elapsed between the moment that I so made contact (or fired) and the arrival of the wave of impulse through the rocks of the range or wave-path, when made visible by, and observed by me in, the seismoscope.

For this purpose such an arrangement was required as, upon contact being made by me at the observing-shed (O), should set in motion such a contrivance, situated upon the quarry cliff, at the remote end of the telegraph wires, as should there instantly close the poles of the great (Grove's) firing-battery and so fire the mine, and in the event from any cause of this result not taking place at the preconcerted moment, that then it should be free to Mr. Cousens or his assistants to close the poles of the firing-battery by hand in the ordinary way.

[illegible]

[illegible]


The Telescope

In Pl. IV., in which (fig. 1) this arrangement is figured (without reference to scale), A is one of the headings seen in the cliff-face at part of the quarries. Above the cliff at B is placed the Grove's firing-battery; the conducting wires from its poles pass down the face of the cliff and into the heading, uniting at the platinum priming-wire in the midst of the charge of powder, the further end of the wires terminating in mercury-cups at the contact-maker C (about to be described). From the electro-magnet of the contact-maker, the two insulated wires are led along upon telegraph poles from the summit of the cliff down to the observer's station at Pen-y-Brin, where they terminate also in mercury-cups, one forming the $\epsilon +$ and the other the $\epsilon -$ pole of the contact-making battery E placed there. This battery consisted of six of the usual moistened-sand batteries in use for telegraph purposes.

The chronograph (D) was placed upon the levelled rock adjacent to this battery, and conveniently for its lever (*m*) being acted on by the left hand of the observer, when lying at full length upon the ground, with his eye to the seismoscope based upon the rock at F, its optic axis being situated in the vertical plane of the line of wave-path or range F A, close to the seismoscope, and at the same level as the eyepiece of that instrument. A very good achromatic telescope was adjusted upon its stand, so as to bring the heading about to be experimented on, together with the whole face of the cliff and the firing-battery, &c., within its field,—the eyepiece of this telescope being fixed at about a distance of 6 or 8 inches from that of the seismoscope, and so that the eye of the observer, while lying at ease and with the left hand upon the lever of the chronograph (*m*), could be instantly transferred from the one instrument to the other. In this state of things, when the proper signal (by the exhibition of a red flag) was made, and at a preconcerted time as nearly as was practicable, by those stationed at the firing-battery at B, that "all was ready," I applied my eye to the seismoscope, and pressed down the lever (*m*) of the chronograph with a sharp rapid movement; this instantly closed the poles of the contact-making battery C, causing the galvanic current to pass through the electro-magnets of the contact-maker away at the quarries at C. This directly closed the poles of the Grove's firing-battery at B, and fired the mine. The moment I observed the arrival of the wave of impulse propagated through the range from the explosion at A in the seismoscope at F, I withdrew my hand from the lever of the chronograph (*m*), and thus stopped the instrument, the interval of time between its having been started and stopped thus registering the (uncorrected) time of transit of the wave for the distance A F. It will now be necessary briefly to describe the several instruments separately. The seismoscope and chronograph have been already fully described in the account of the experiments made in 1849 at Killiney and Dalkey (Second Report on Earthquakes, &c., Report of Brit. Assoc. 1851), to which reference may be made.

Briefly, the seismoscope (fig. 3*, Pl. IV.) consists of a cast-iron base-plate, on the centre of the surface of which is placed an accurately formed trough (*b*), 12 inches long, 4 inches wide, and 2 inches deep, containing an inch in depth of pure mercury, with its surface free from oxide or dust, so as to reflect properly. The longer axis of this trough is placed in the direction of the wave-path, the base of the instrument being level. At the opposite end of the trough are placed standards with suitable adjustments: that at the end next the centre of impulse carries a tube (*c*), provided with an achromatic object-glass at its lower end, and a pair of cross wires (horizontal and vertical); its optic axis is adjusted to 45° incidence with the reflecting surface of mercury in the trough. At the other end of the trough an achromatic telescope (*a*) with a single wire is similarly adjusted, so that when the moveable blackened cover (*e e*) is placed over the trough, &c., no light can reach the surface of the mercury except through the tube *c*. The image of the cross wires in the latter is therefore seen through the telescope *a*, clearly reflected and defined in the surface of the mercury, so long as the fluid metal remains absolutely at rest; but the moment the slightest vibration or disturbance is by any means communicated to the instrument, the surface of the fluid mirror is disturbed, and the image is distorted, or generally disappears totally. The telescope magnifies 11·39 times linearly, and the total magnifying power of the instrument to exalt the manifestation to the eye of any slight disturbance of the mercurial mirror is nearly twenty-three times. Its actual sensibility is extremely great. In the present case, however, this was not needful, as the impulse transmitted from these powerful explosions produced in all cases the most complete obliteration of the image, and in those of the most powerful mines experimented on caused a movement in the mercury of the trough that would have been visible to the naked eye. Indeed, in that of the 24th November, 1860, the amplitude of the wave that reached the seismoscope was so great as to cause the mercury to sway forwards and backwards in the trough to a *depth* that might have been measured.

After the earth-wave has reached this instrument, a certain interval of time is necessary for the production of the wave in the mercury, and for its transit from the end of the trough next *c*, where it is produced, to the mid-length where it is observed. This involves a correction in the gross transit-time as observed with it. For the methods by which the constant for this (seismoscope correction) was determined I must refer again to Report of Brit. Assoc. 1851, pp. 280, 281. It amounts to 0″·065 in time; and as the effect of this will in every observation appear to *delay* the arrival of the earth-wave at the instrument, this constant in time, converted into *distance*, must be *added* to the rate of wave-transit otherwise obtained.

The chronograph (originally devised by Wheatstone) is shown in fig. 1*, Pl. IV. It consists, in fact, of a small and finely made clock, deprived of its pendulum, but provided with a suitable detent (shown more at large in fig. 4*), by which the action of the weight upon it is kept always arrested, but can immediately be permitted to take place in giving it motion, upon pressing the hand quickly upon the lever *g*.

The running down of the weight causes the anchor and pallets of the escapement (*h*) rapidly to pass the teeth of the escapement-wheel (*a*), so that the clock "runs down" by a succession of minute descents; and thus the motion is practically a uniform one. It follows that as more weight is added this velocity becomes greater, and by such addition the instrument may be made to measure more and more minute fractions of time.

It registers time upon two dials (fig. 2*), each with an index: one of these is fixed on the axis of the escapement-wheel (*a*), and its dial is divided into thirty smaller and six larger divisions; the pinion on this axis is to the wheel upon the weight-barrel (*b*) as 1 : 12. This carries the other index, and its dial has twelve divisions, so that one of its divisions corresponds to an entire revolution of the former one. The value in actual mean time due to the movement of the instrument, as thus recorded, requires to be ascertained by reference to a clock beating seconds, so that the number of revolutions of the index *b*, and parts of revolutions of that of *a*, during an interval of, say, 30 seconds, may be determined by the mean of several experiments. For the methods of performing this with the necessary correctness, I again refer to

"Second Report on Earthquakes," &c., Report of Brit. Assoc. 1851, pp. 287, 289, &c.

On the present occasion, as a considerable time elapsed between the successive experiments, during which the oil on the instrument more or less changed its state, and as some were made in summer and others in winter, it became necessary to rate the chronograph anew for each experiment, or at least to verify the former rating; for this end it was necessary to provide a suitable loud-beating seconds clock with a divided arc to the pendulum, as none such could be procured at Holyhead. The same weight was constantly used with the chronograph, and the extreme differences found in the rating during the several years that these experiments have been in progress were no more than the following:—

Nov. 1856. Value in mean time of one division of the dial (*a*) = $0''.01485$
May 1861. Value of same . . . . . . = 0.01806

Taking for illustration the former value of the smallest division of the dial (*a*), we see that each division of the dial (*b*) is equal to one revolution of the index (*a*), and equal to

$$0''.01485 \times 30 = 0''.4455,$$

and one revolution of the index (*b*) equal to

$$0''.4455 \times 12 = 5''.346,—$$

an *absolute* rate of movement of the instrument not widely differing from that employed in the experiments of Killiney and Dalkey, with which it is desirable that the present results should be comparable. Half a small division of the chronograph can be read; we therefore in these experiments possess the means of recording time to within $0''.0074$, or to nearly $\frac{7}{1000}$ths of a second.

The additional apparatus of the chronograph consisted merely of such arrangements that the releasing lever (*g*), when pressed down by the hand applied to the wood insulator at *m*, should dip at *i* into a mercury-cup, and so make contact by the wires (*b*, *b'*) between the poles of the contact-making battery (E).

It remains to describe the contact-maker (fig. 2, Pl. IV.). *c* is the base of the instrument of mahogany, carrying a vertical and bent arm (*d*) of cast iron, into the upper forked end of which the central iron bars, of about $\frac{7}{8}$ths of an inch in diameter, of the electro-magnets *a*, *a* (seen in plan in fig. 3) are secured by a cotter; the coils of covered wire round these are continuous, the wire (*b*) from the $\epsilon +$ pole passing at its further end from the first coil over to the second, and at the extremity of the latter passing off to the $\epsilon -$ pole by *b'*, the junctions being effected by mercury-cups in the usual way. *n* is a sliding piece of wood, secured upon the base *c* when adjusted in place by the screw at *s*; this carries a wrought-iron lever armature (*c*), whose arms are as 8 : 1, the shorter and rather heavier end being adjusted so as to be beneath the poles of the electro-magnets, and at such a distance beneath them that, upon passing the current through the coils, the magnets shall readily attract the short end of this lever, snatch it up into contact with the poles of the magnets, and in doing so depress the other or remote end of the lever. The latter extremity of the lever is provided, as seen more at large in figs. 4 and 5, with a forked pair of copper poles amalgamated, which, when depressed by the action of the electro-magnets, dip into the mercury of the cups *f* and *f*, and in doing so close the holes of the firing-battery, the conducting wires from which (*h* and *h*) dip respectively into mercury-cups, which by a tube bored through the wood are in permanent communication with *f* and *f* (cups) respectively. The lever and forked poles, &c.,

are provided with various screw adjustments as to position, range, &c., and a slender spring beneath the lever, ensuring that it shall not be accidentally moved by wind, or other cause, until acted on by the powerful grasp of the magnets.

This instrument was found to answer admirably well. It may be observed, in passing, that it gives the means of exploding mines at almost any distance through telegraphic wires, and by any moderate contact-making power, and may admit of valuable applications hereafter for the explosion, at a determinate instant, of mines for purposes of warfare.

It is obvious that a certain *loss* of *time* must occur at this contact-maker, in reference to our experiments—that, in fact, the total time registered by the chronograph at D is too great by the minute interval that elapses between the arrival of the galvanic current in the coils at *a* and the dipping of the poles *f*, *f* into the mercury-cups. With the same battery power at E and conducting wires, this *delay* is practically constant. Its amount, however, required to be determined, and the *time*, when converted into *distance*, *added* to the gross transit-rate previously ascertained.

For this purpose the following little apparatus was employed. Its principle, though not the precise details of its construction, is shown in fig. 6, Pl. IV. Upon a vertical steel spindle (*s*) revolving upon an agate step at bottom, and in a polished brass collar at top, a cylindric barrel is placed, of 1 inch diameter, having an escapement-wheel and anchor-escapement (*v*) at its lower end, all the parts being made as light as possible. Upon the upper end of the spindle a circular disk of Bristol board (cardboard), *f*, of $12\frac{3}{4}$ inches diameter, is secured by a light screw collar (*t*) gripping the disk firmly, so that it and the spindle must revolve together. Both the upper and under surfaces of the card-disk, for an inch or two from the circumference, towards the centre, were slightly rubbed with violin-player's *hard* rosin, and the whole, resting upon its base B, placed so that the disk should rotate horizontally. A fine *elastic* silk thread is wound a few turns round the barrel, and passing over the sheave (*r*) sustains a weight (W), by the descent of which, when required, rotation can be given to the disk, &c., the weight itself being large in proportion to the inertia of the rotating parts. By suitable changes in the disposition of the parts of the contact-maker (chiefly in getting the cast-iron arm *d*, fig. 2, out of the way), it was placed at C with respect to the disk; so that the lower poles of the electro-magnets (*a*, *a*) were just above the upper surface of the card-disk, and the short end of the lever armature (*e*) just below the same, the card running free in the small space between, and the centre of the magnet-poles being exactly at a radius of 6 inches from the centre of the disk. Nearly at right angles on the disk to this, the chronograph (D) was placed and firmly fixed: a fixed point (shown in part only in the fig. *g*), formed of a bit of cylindrical mahogany, with its lower end rosined, was so fixed as to be about $\frac{1}{12}$th of an inch above the upper surface of the disk. The lever (*m*) of the chronograph, divested of its forked pole, and having a small rectangular rod of brass substituted, was so adjusted that its sustaining spring beneath should press this brass terminal up against the under surface of the disk at *p*, directly below the fixed point or stop (*g*), and bending the cardboard there, press its upper surface into contact with the lower end of *g*.

Thus the weight W being free to descend, this arrangement at *p* acted as a detent to keep the disk from moving; but when the lever (*m*) was pressed down to start the chronograph, the disk immediately became released, and began to revolve by the action of the weight W. At E the contact-making battery, or one of equal power, was placed, one of its poles being connected, through the rheostat (R), by conducting wires with the coil of the electro-magnet (*a*), and terminating at the $\epsilon+$ pole at the mercury-cup (*n*), which was in connexion with the other or $\epsilon-$ pole of the battery.

The rheostat was adjusted so that the resistance equalled that of the conducting wires along the telegraphic poles between C and D, E (fig. 1, Pl. IV.). In this state of things, when the lever (*m*) of the chronograph was pressed down, the disk (*f*) instantly commenced rotating; but directly afterwards the electro-magnet (*a*), whose current was established by the first movement, attracted the lever armature (*e*) through the disk, and the latter was arrested by being gripped between the pole of the magnet and the armature. The arc of the circumference of the disk then, at the centre of the magnet-pole (*i.e.* with 6 inches radius), that was intercepted between the marked spot (*p*) whence it started and that at which it was arrested, became a measure of the time lost or elapsed between starting the chronograph at the observer's station and making contact at the firing-battery in the actual experiments.

The arc thus intercepted was converted into time, from the descent of the weight (W), by the common formula $t=\frac{\sqrt{s}}{4}$, *s* being given and equal to $\frac{1}{12}$th the length in feet of the arc described by the circumference of the disk before being arrested; and this was capable of being controlled by measuring by the chronograph itself the actual time of a given number of successive revolutions, and parts of revolutions, of the disk. The total number of complete revolutions made being taken by reckoning the coils wound off the barrel upon a mean of ten experiments with this apparatus, the delay at the contact-maker appeared to be no more than $0''\cdot0143$, which converted into distance, at the greatest transit-rate observed, gives a correction of 17·3 feet per second, and at that of the least of 12·8 feet per second, both additive.

It may be remarked that the small error due to inertia, &c. in this apparatus tends nearly to correct itself, the extremely small time lost at starting of the disk being very nearly equalled by its tendency to be carried a little too far by the velocity impressed. The whole inertia also of the disk, barrel, &c. was extremely small in proportion to the moving weight W.

Another correction requiring to be attended to in these experiments was the *time* of *hang-fire* in the charge of the mine, that is to say, the time required for the burning of such a portion of the whole charge of powder as should be sufficient to rupture the rock around, and so start off from the focus the wave-impulse perceived in the seismoscope—in other words, the time lost between the instant of first ignition of the powder, viewed as simultaneous with that of making contact at the firing-battery B, and the starting of the wave of impulse to be measured.

In my former experiments at Killiney Bay, it will be recollected that it was in my power to determine this experimentally and rigidly, the moderate charges of powder there employed admitting of this, and that I found it amount for 25 lbs. of powder to $0''\cdot050513$, or to about $\frac{1}{20}$th of a second. Such is, in fact, the time that the full charge of a 68-pounder takes to burn. But in the present case direct experiment was impossible, and the value for this correction can only be approximately obtained by observing the time that elapsed in some instances between the moment of making contact at B, and the first great visible movement of rock at the face of the heading. This observation I made in three instances, noting the time by a delicately made chronoscope, by M. Robert, Rue du Coq, Paris. The results gave $0''\cdot05$, $0''\cdot04$, and $0''\cdot8$ for the time of hang-fire respectively, noting from the first visible movement of rock at the face of the heading. This would give a mean of $0''{\cdot}0566$, or very nearly $0''{\cdot}06$ for the time of hang-fire, which can be viewed, however, only as an approximation. It must vary slightly with every different "heading," depending as it does upon a great variety of conditions, but probably much more upon the exact proportion subsisting in any given case between the actual resistance of the rock to the powder employed, than upon the absolute quantity of the latter, although the total mass of powder burnt is also an element. The greatest *observed difference* between the greatest and least hang-fire amounted to $0''{\cdot}03$, which, converted into distance at the mean transit-rate of our experiments, would give a *possible* maximum error due to this cause of about 31 feet per second. The probable error cannot be more than about one-half that amount. This correction, converted into distance, is also additive.

By the methods thus described the experiments were commenced and conducted up to the middle of 1857; great trouble and difficulty, however, were experienced from the outset in keeping the arrangements in working order, and so as to be efficient when wanted at the very brief notice that could be afforded me beforehand by the officers in charge of the works, when suitable headings were about to be fixed. The entire line of telegraph wires, the observer's shed, &c., were exposed to mischief and depredation, and to injury in that tempestuous place by storms, &c. The long intervals between the experiments involved preparations and adjustment of every part of the galvanic apparatus afresh upon each occasion; and for the most trifling repairs workmen had to be brought from Conway, or even from Manchester, as also, in every case, to make good the branch-conductors from the telegraph wires. The length of the range and hilly character of the ground also produced much difficulty in being assured that all was right from end to end against the moment at which the firing was obligatory, as well as great personal fatigue at a moment when composed ease and freedom from fatigue were most desirable for good observation.

These difficulties, in great part foreseen, had early caused me to turn my attention to the practicability of so adjusting at the observing-station a telescope of large field and clear definition, and so disposing the Grove's firing-battery and other apparatus at the quarry cliff, that all could be clearly seen from the former point, and the act of making contact at the firing-battery observed by myself with distinctness and certainty, the two extremities of the range being thus, as it were, visually brought together.

Two attempts to experiment in the summer and autumn of 1857, rendered abortive by derangements of the galvanic apparatus, caused me finally to abandon it, though unwillingly. I found, however, with some satisfaction, that, subject to the *possible* fatality of a cloud settling over the quarry cliff, and so shutting it out from sight just at the critical moment, the telescopic arrangement, on trial, really seemed to offer quite as accurate results as the more complex method, and more difficult to manage, of galvanic contact-making; and the new mode was thus continued to the end of the experiments. The firing-battery being so disposed upon the sloping brow of the quarry cliff facing my station as to be clearly visible to me, as well as every movement of those employed there, a code of signals was arranged between myself and Mr. Cousens, by which we should mutually become cognizant of the state of preparation, &c., and successive acts at our respective stations. When all was ready at both ends for the explosion, the final signal was made by Mr. Cousens, by elevating a bright red flag (mounted upon a short and light staff) to a vertical position, the lower end resting on a fixed point; a prearranged interval of a few seconds (usually $10''$) intervened, when he dropped the red flag, rotating it upon the lower end of the staff held in the right hand, and with the left made contact of the poles of the firing-battery at the same instant that the flag reached the horizontal position. Standing facing me, and as distinctly observable by me upon each occasion as though I had been close beside him, my own eye and attention were directed to Mr. Cousens's left hand; at the instant that I observed the contact made by him, I released my chronograph, and at once transferred my eye from the eyepiece of the observing-telescope to that of the seismoscope. A moment elapsed before my own eye adjusted itself to the focus of the latter; but the length of transit-period of the wave (always above 4″) gave ample time for this, and then at the disappearance of the cross wires, as in the former case, I arrested the chronograph. The only source of time-error introduced by this plan was that of the probability of some slight inequality of speed in dipping the poles to make contact on Mr. Cousens's part (which may be called his personal equation), and the introduction of a somewhat larger value than before to my own personal equation—in the former arrangement that being due to consent between my *hand* and observation by the *eye* of *one* object, in the latter between the *hand* and observation of *two* objects. As regards the first, several experiments were made by Mr. Cousens and myself at the firing-station, by his repeatedly lowering the red flag and making (the movement of) contact, the contact-maker (fig. 2, Pl. IV.) and chronograph being so arranged as to register the total interval of time in each case between the first visible motion of the red flag and the completion of contact; others were so made as to register the time between the horizontal position of the red flag and the completion of contact. The result gave a minimum error of 0″·009, and a maximum of 0″·017. The mean error, 0″·013, is thus almost equal to the constant due to the contact-maker (in previous arrangement), with this difference, however, that the error in the present case *might* be either + or —. In twelve experiments nine were +, or additive; that is to say, the contact was made more slowly with the left hand than the flag was dropped with the right. The probability is therefore 3 : 1 that the error would be always additive, and would not exceed 0″·013, even if my observation was wholly directed to the flag; but as I directed my attention as completely as possible only to the movement of the contact-making hand, it is still less, and therefore, as not amounting to more than 6 or 7 feet per second in transit-time, may be neglected altogether. As regards my own personal equation of observation, it will be seen, on reference to "Second Report," &c. (British Association Report, 1851, p. 305, &c.), of the former experiments at Killiney, where it was ascertained for both observers that its amount is much too minute to enter sensibly into the present results; and it is needless to say that this is *à fortiori* the case as respects the time lost in transmission of the galvanic current through the 12,000 or 13,000 feet of conducting wire.

The diagrams (Plate III.) give, to one scale, horizontal sections of the several headings from the experiments on which transit-results have been deduced, and a vertical section also of No. 31, quarry No. 9, as illustrative in this respect of all the others. The line of heading, from the face of the cliff up to any focus of charge, turns, it will be seen, thrice at right angles to itself, the object being more effectually to confine the effort of the powder when fired, and prevent the mass of "tamping" from being blown out. Results have been deduced from two headings, each of single focus, two of double focus, one of triple focus, and one of four foci,—the face of the cliff blown out varying, as marked in each case in the figure, from 60 feet to 120 feet in height, and the total weight of powder fired at one time being from 2100 lbs. up to the enormous charge of 12,000 lbs., or nearly 6 tons.

It was necessary to ascertain the exact distance in a right line from each of these headings, wherever situated, to the observing-station O, at Pen-y-Brin; and for this purpose, previously to each explosion, the distance of the mouth of the heading was measured with accuracy (which the ground admitted of) from the flagstaff at W (see Map, Plate II., and Section 1, Plate III.), the exact distance of the latter having been previously determined from the observing-station O, as already described.

The angle of azimuth made at the flagstaff by the line of constant range (O W), and by the line joining the flagstaff and mouth of the heading, was observed in each case, and we thus had the requisite data, from which was calculated, by the usual formulæ,

$$\tfrac{1}{2}(A+B)=90^\circ-\tfrac{1}{2}C,$$
$$\log\tan\tfrac{1}{2}(A-B)=\log(a-b)+\log\tan\tfrac{1}{2}(A+B)-\log(A+B),$$

C being the observed angle, a and b the known sides from flagstaff to O, and from flagstaff to the mouth of the heading.

Thus the actual range of wave-transit from the focus of each explosion to the seismoscope at O was finally obtained. The positions respectively of each are marked by a black dot, and numbered in order of the date of experiment upon the Map (Plate II.), taken from Mr. Rendel's chart of 1850, published by the Admiralty. Upon it the measured base (A B), and triangulation for obtaining the constant range (O W), and for checking that measurement, are marked. The actual wave-paths are therefore in right lines from the dots No. 1, No. 2, No. 3, &c., to the point O. The coast-line and position approximately of the cliff-faces of the quarries, and the superficial line of junction of the quartz-rock and of the slate, are also marked. The great clay dyke passing through the quartz rock at the quarries in rear of the headings is marked by a pair of interrupted lines.

The Map is to a scale of $1\frac{1}{4}$ inch to 1000 feet, but is not quite exact as to filling in details on land; the important distances here concerned are therefore marked in by figures.

In the opposite Table (p. 217) our chief numerical results are comprised at one view.

The first result that strikes the eye at once in regarding the Table (p. 217) is, that, with the exception of the experiment No. 1, all show that the transit-rate tends to increase in velocity with the increased quantity of powder fired,—in other words, that the loss of velocity in the same rock is less, in some proportion, as the force of the originating impulse of the wave is greater, and its amplitude greater therefore on starting.

This is apparent if the uncorrected transit-rates (col. 8) be arranged in the order of increased weights of powder exploded, thus:

Table II.

Number of experiment	2	3	1	6	4	5
Weight of powder	lbs. 2100	lbs. 2600	lbs. 3200	lbs. 4400	lbs. 6200	lbs. 12,000
Uncorrected transit-rate (feet per second) ...	967·93	977·26	896·12	996·11	1173·87	1210·79

Experiment No. 1 forms the only exceptional case, and the departure is not a wide one; so that the result cannot be viewed as accidental or due to any balancing of errors, but as the expression in so far of a fact of nature.

TABLE I.

Wave-transit Period.—Experimental Results. Holyhead.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Date of firing heading.	Number of the heading.	Number of the quarry.	Weight of powder exploded.	Approximate weight of rock removed.	Total distance of mean centre of heading from observer.	Total observed time of transit.	Observed rate of transit per second, uncorrected.	First time correction for the seismoscope + in distance.	Transit-rate with first correction (col. 9).	No.
			lbs.	tons.	feet.	seconds.	feet per sec.	feet per sec.	feet per sec.	
1856, Nov. 13	No. 46.	No. 9.	3,200	10,000	6582·93	7·346	896·12	58·248	954·368	1
1856, Nov. 13	No. 10.	No. 3.	2,100	7,500	5476·57	5·658	967·93	62·915	1030·915	2
1857, May 16	No. 31.	No. 9.	2,600	9,000	6377·14	6·524	977·26	63·522	1040·782	3
1857, Dec. 18	No. 33.	No. 9.	6,200	20,000	6403·48	5·455	1173·87	76·302	1250·172	4
1860, Nov. 24	No. 80.	No. 3.	12,000	36,000	5038·13	4·161	1210·79	78·701	1289·491	5
1861, May 11	No. 84.	No. 4.	4 400	13,000	5228·59	5·249	996·11	64·747	1060·857	6

Nor is it due to relative differences of different experiments in the lengths of range, in the quartz rock and in the slate respectively, as might be imagined; for the experiments Nos. 2, 5, and 6 had wave-paths of about 1400 feet in quartz only, and embrace the lowest and the highest velocities, while Nos. 1, 3, and 4 had about double this range or wave-path in quartz, with velocities not widely different from each other, or from No. 2.

There are four corrections altogether applicable to the uncorrected transit-rates, col. 8, Table I., as already referred to, viz.—

1st. That for the liquid wave in the seismoscope, which, as a delay in *time*, is, when converted into distance, always +. This correction has been already applied in cols. 9 and 10, Table I.

2ndly. That for the *time* of hang-fire of each explosion in the rock, the constant in time for which has been given, $=0''\cdot056$.

It appeared, however, uncertain whether this should be converted into distance, as probably nearly constant for every experiment, or in what way it might be variable, in relation to the weight of powder, and other circumstances of each. The result disclosed in Table II., however, appears to indicate that the conversion into distance should be proportionate to the respective gross or uncorrected transit-rates, assuming, as we may now do, that these are functions of the originating impulses and resistances together, in each instance. This may not be absolutely true, but is the nearest approximation we can make. This correction in distance is also always +.

3rdly. The loss of time at making contact,—whether galvanically, in which we ascertained the constant in time to be $=0''\cdot0143$, when converted into distance always +, or by the hand (of the firing party), when we found it was in time $=0''\cdot013$, which in distance might be either + or —.

The probability being so much in favour of the latter being positive, I have ventured to apply it as always so, which also renders all the experiments more truly comparable.

4thly. The personal equations of the observer and time of transit of the galvanic current, both of which may be neglected.

Applying these several corrections, we obtain the following Table and final numerical results:—

TABLE III.—Wave-transit Experiments. Corrected Results.

No. of exper.	1. Observed rate of transit per sec., uncorrected, col. 8, Tab. I.	2. 2nd correction, for hang-fire of explosion taken in distance.	3. Transit-rate with 2nd correction, col. 2+col. 10, Tab. I.	4. 3rd correction, making contact into distance.	5. Final corrected transit-rates, col. 3+col. 4.
	feet per sec.	feet per sec.	feet per sec.	feet per sec.	feet per sec.
1.	896·12	50·183	1004·551	11·649	1016·200
2.	967·93	54·204	1085·119	13·831	1098·958
3.	977·26	54·726	1095·508	13·975	1109·483
4.	1173·87	65·737	1315·908	15·260	1331·168
5.	1210·79	67·804	1357·295	15·740	1373·035
6.	996·11	55·792	1116·649	12·949	1129·598

The limits of error in these results would seem to be, that the 2nd correction may amount to 15·5 feet per second in excess, and the error from all other instrumental or observational sources may be estimated probably at not more than 10 feet per second, so that the results may be deemed true to within $25\frac{1}{2}$ feet per second + or —.

The general mean derivable from the whole of the experiments taken together gives 1176·407 feet per second for the transit-rate. The results, however, obviously form two groups, viz. Nos. 1, 2, 3, and 6 from the smaller charges of powder, and Nos. 4 and 5 from the greater ones.

The mean from the four first is 1088·5597 feet per second, and that from the two last is 1352·1015 feet per second; and taking a mean of means from both of these, we obtain a final result of 1220·3306 feet per second as the mean transit-velocity of propagation, in the rocks experimented on, of a wave-pulse produced by the impulse of a charge not exceeding 12,000 lbs. of powder. We may be justified in concluding that the velocity of wave-propagation (or transit) really does increase with the force of the original impulse; it would be vain, however, to attempt to deduce the law of such increase from the results before us.

The experiments of Mr. Goldingham at Madras, on the retardation of sound in moist air, and the theoretical researches of Mr. Earnshaw, both, by analogy, rendered *à priori* probable what is now for the first time, so far as I am aware, experimentally shown.

It follows, then, on reference to my former experiments at Killiney Bay, that the rate of wave-propagation in highly stratified, contorted, and foliated rock is intermediate between that for dense wet sand and for discontinuous and shattered granite. Adopting the first mean from the smaller charges of powder, as better comparable with the Killiney experiments, which were made with charges of only 25 lbs. of powder, and which would doubtless have been higher velocities with heavier charges, we obtain the following series:—

Transit-rates of Wave-propagation.

In wet sand	824·915	feet per second.
In contorted and stratified rock (quartz and slate)	1088·559	" "
In discontinuous granite............	1306·425	" "
In more solid granite	1664·574	" "

We may infer, even adopting the highest mean of these experiments (1352·101 feet per second) for comparison with the transit-rate for discontinuous granite, and bearing in mind that the former velocity is due to the impulse originated by a *mean* charge of 9100 lbs. of powder, while the latter was due to one of but 25 lbs., that for equal originating impulses the rate of propagation of waves analogous to earthquake-waves of shock must be less generally, if not always, in contorted stratified rocks than in crystalline igneous rocks analogous to granite, the amount of shattered discontinuity being the same in both.

The general mean obtained, viz. 1220·33 feet per second = 13·877 statute English miles per minute, coordinates, as might be expected, with the more trustworthy of the older attempts to determine the velocity of propagation of earthquake-waves in nature (see Table 8, "Second Report on Earthquakes," &c., Report of Brit. Assoc. 1851, p. 316), and still more so with the more recent and exact determinations of such velocities made by Nöggerath*, who found it 1376 Paris feet per second; by Schmidt†, of the shock about

* Das Erdbeben vom 29 Juli, 1846, im Rheingebiet, &c. V. Dr. Jakob Nöggerath. 4to, Bonn, 1847.

† Untersuchungen über das Erdbeben am 15 Jan. 1858. J. F. Schmidt, Astronom, Mittheilungen der Kais.-Königl. Geog. Gesellschaft, 11. Jahrgang, 1858.

Mincow in Hungary, and by myself in the (late) Neapolitan kingdom, after the great shock of 1857, where I found that the velocity of propagation in the shattered limestone and argillaceous rocks of the shaken region was even below what has been here determined for the harder and more compact rocks of Wales, also of stratified structure. Experiment and observation have thus alike sustained the three provisional conclusions anticipated by me as to the transit-velocities of earthquake-waves in nature (at the conclusion of "Second Report," &c., Report of Brit. Assoc. 1851, p. 316), in passing through formations different in character.

In experimenting with these great explosions at Holyhead, I have been enabled to see that such great impulses, though offering the advantages of a greatly extended range, and hence larger total time-period for measurement, do not in reality admit, from various contingent circumstances, of greater, or perhaps of as great accuracy of transit determinations, as do much smaller explosions, such as those specially made at Killiney Bay. These great explosions, however, elicit phenomena visible in the seismoscope, which are too faint to be distinct when due to smaller charges, and which analogize closely with the succession of vibratory and wave movements observed in natural earthquakes. In the larger of these great explosions, as the impulsive wave approached the instrument, the previously steady reflected image of the cross wires did not at once disappear; the definition of the wires rapidly became obscured, the obscuration increasing for an instant to a flickering of the image, preceding its obliteration, at the same moment that the oscillation then communicated to the trough caused the mercury to sway from end to end, in a liquid wave, whose amplitude was sufficient to cause variable flashes of light to be transmitted to the eye, with the changing inclination of the reflecting-surface of the undulating mirror,—the image of the cross wires reappearing (but now oscillating with the movement impressed upon the mercury in the direction of the wave-transit) by passing through a second phase of flickering and vibration, but in the reverse order, before becoming perfect in definition as at the commencement.

I had thus presented visibly before me the "tremors" that nearly invariably are described as preceding and following the main shock and destructive surface movement in every great earthquake. The phenomena appear to be identical, however premature it may be to propose a precise and adequate explanation of their production.

There appear to be *three* elements upon which the wave-transmissive power of a rock-formation mainly depends, viz. the modulus of elasticity of its material, the absolute range of its compression by a given impulse or impact, and the degree of heterogeneity and discontinuity of its parts. As has been already described, the range of wave-transit of these experiments passed through two rock-formations, quartz and slate, differing in name and in several respects in structure, yet very much alike, as has been remarked, in intimate composition. It remains to show experimentally that they do not differ in these conditions of transmissive power to such an extent as materially to affect the results.

If a perfectly elastic ball be dropped upon a mass of perfectly elastic rock, whose volume may be considered as infinite with respect to that of the ball, the latter will rebound to the height from which it descended; and if the same ball, though not perfectly elastic, be dropped in succession upon like masses of two different rocks, it will rebound from each to a height less than that from which it fell, and the value of which will depend mainly upon the elasticity, the depth of the impression, and the degree of discontinuity of the rocks respectively. We have therefore thus got the means of very simply determining, in a sufficiently approximate manner, the relation between the velocity of impact and that of recoil, a quantity that bears the most intimate relation to the wave-transmissive power of rocks or other like bodies. To conduct this experiment I dropped an ordinary ivory billiard ball upon a number of different masses of the quartz-rock, and also of the slate, both *in situ*, and upon very large isolated blocks, making the impacts both transverse to the stratifications and foliation and in the same planes as these, in both sorts of rock. The ball was dropped from a constant height of 5 feet above the point of impact, and beside a graduated scale held vertically by an assistant, by means of which, after a little practice, and skill in choosing by trial a point of impact, from which the ball shall rebound vertically only, it is easy to observe with considerable accuracy the height to which it recoils, the eye being gradually brought to the same level as that to which the ball rises, so as to read the scale free from parallax.

If H and h be the height from which the ball has fallen and that to which it rebounds, then

$$\frac{\sqrt{2gh}}{\sqrt{2gH}} = \frac{v}{V} = R,$$

which may be viewed as a symbol of the above relation, and closely connected with the wave-retardation respectively. In the quartz-rock I obtained the following results:—

From the hardest and densest blocks or masses, and edgeways to the lamination, the ball recoiled 2·33 feet; v is therefore $= s\sqrt{h} = 12{\cdot}251$ feet per second.

From the softer and more earthy masses, and transverse to the planes of lamination, the recoil was 1·50 feet, and $v = 9{\cdot}822$ feet per second.

And in the slate-rock,—

From the hardest and densest, edgeways to the foliation, the ball recoiled 2·00 feet, or $V = 11{\cdot}341$ feet per second.

From the least hard and dense, and transverse to the planes of foliation, the recoil was 1·417 feet, and $v = 9{\cdot}546$ feet per second.

The mean value for the quartz rock is thus

$$v = \frac{12{\cdot}251 + 9{\cdot}822}{2} = 11{\cdot}036 \text{ feet per second};$$

and for the slate rock,

$$v = \frac{11{\cdot}341 + 9{\cdot}546}{2} = 10{\cdot}443 \text{ feet per second};$$

and as $H = 5$ feet, $V = 17{\cdot}935$ feet per second, we have

$$R_s = \frac{10{\cdot}443}{17{\cdot}935} = 0{\cdot}576 \text{ for the slate,}$$

and

$$R_q = \frac{11{\cdot}036}{17{\cdot}935} = 0{\cdot}553 \text{ for the quartz,}$$

numbers which differ so slightly from equality as to indicate that there is no great difference of transmissive power in the two rocks. Indeed this is rendered certain by consideration of the experiments themselves. Previously to their commencement I expected that in every instance the range in quartz would have been extremely short in relation to that in slate, and very nearly the same in all cases. The circumstances of the works subsequently obliged me to increase the range in the quartz, and to adopt "headings" for experiment, three of which have a range in quartz of nearly double that of the other three, as seen in the two following Tables:—

Table IV.—Shortest Ranges in Quartz.

No. of experiment.	Uncorrected transit-rate.	Range of quartz.	Range of slate.
	feet per sec.	feet.	feet.
2	967·93	1600	3877
5	1210·79	1300	3738
6	996·11	1400	3829

Uncorrected mean transit-rate of Nos. 2, 5, 6 ....1058·27 feet per second.
Ratio of ranges in quartz to slate .... 1 : 2·66.

Table V.—Longest Ranges in Quartz.

No. of experiment.	Uncorrected transit-rate.	Range of quartz.	Range of slate.
	feet per sec.	feet.	feet.
1	896·12	2850	3733
4	1173·87	2700	3704
3	977·26	2650	3727

Uncorrected mean transit-rate of Nos. 1, 4, 3 .... 1015·75 feet per second.
Ratio of ranges in quartz to slate.........1 : 1·32.

In each of the two groups everything is as nearly as possible alike; there are two explosions of moderate charges and one great explosion in each. They differ only in this, that in the first group (Table IV.) the range in quartz, in proportion to that in slate, is very nearly double that in the latter (Table V.), being in the ratio of 2·66 : 1·32; yet, as will be observed, the mean transit-rate in both groups is almost alike, being in the ratio of 1058·27 : 1015 : 75. This would be obviously impossible if either one rock or the other exercised any well-marked accelerating or retarding influence upon the transmission of the wave.

In their direct relation to seismology the interest of the foregoing results is not as great as when some years since I commenced these experiments. At that period no knowledge whatever existed as to the relation that subsists in nature between the velocity of transit and the velocity of the particles in wave-movement in actual earthquakes. Geological observers, in fact, did not appear to be aware of any such physical distinction; and those who were so, presumed that the velocity of the particles was like that of transit, extremely great, and that some simple relation would probably be found between them.

The first determinations of velocity of the particles in wave-movement that have ever been made, namely, those by myself of the great Neapolitan earthquake of 1857, have dissipated this notion, however, and proved that the velocity of the particles in even the greatest shocks is extremely small, not exceeding 20 feet per second in very great earthquakes, and probably never having reached 80 feet per second in any shock that has occurred in history.

No simple relation appears as yet between the transit-velocity and that of the particles; and however interesting and important both to general physics and to seismology may be further determinations with exactness of the former, it is to the observation and measurement of the latter, by the methods pointed out in the Report upon the Neapolitan Earthquake*, and there employed, that we must look as instruments of future seismological research.

I proceed to lay before the Association the results of some experiments upon the modulus of elasticity of perfectly solid portions of both these rocks, with a view to the interesting question of the relation between the theoretic velocity of transmission, if the rock were all solid and homogeneous $\left(V=\sqrt{2q\frac{\epsilon}{2}},\ \epsilon \text{ being that modulus}\right)$, and the actual velocity found by the preceding experiments.

Subsequently to the conclusion of the experiments at Holyhead, referred to above, I have been enabled to complete a series of experiments upon the compressibility of the rocks which formed my range there, and have determined their moduli of elasticity, &c. The inferences derivable from this latter series form the proper sequel to what has preceded, and they throw some new and not unimportant light upon several points of earthquake dynamics. The experiments were made upon cubes cut from solid and perfect pieces of the rocks by the lapidary's wheel, each 0·707 inch upon the edge—each side, therefore, presenting a surface of 0·5 square inch; and the utmost care was taken to preserve perfect parallelism between the opposite boundary planes, so that, when compressed between hardened steel surfaces, fracture should not result by mere inequality of pressure.

The experiments were made at the Royal Arsenal, Woolwich, with the very accurate and excellent machine used for testing compression and extension of metals in the gun-factory; and I have to express my thanks to Lieut.-Col. Anderson, C.E., the Superintendent of that department, for the valuable assistance afforded me through his attention. The specimens operated on consisted of two each from the following four classes, namely—

The hardest and the softest slate-rock, and the hardest and the softest quartz-rock, which occur within the range or neighbourhood of my experimental explosions at Holyhead; and from each of these classes or varieties of the two rocks, cubic specimens were compressed, 1st, in a direction transverse to the plane of lamination, 2nd, parallel to the same, all the cubes being so cut out of the rock that two sides were, *quam prox.*, parallel to the plane of natural lamination or jointing. The load (50 lbs.) first applied was considered zero, being only sufficient to ensure a complete bearing in all parts of the instrument. The subsequent loads advanced by 1000 lbs. at a time, up to the crushing of the specimen; and at each fresh load the amount of compression was measured by beam-callipers, with instrumental arrangements that admitted of reading space to ·0005 of an inch.

The experimental results, as obtained, are recorded in the following Tables, from No. 1 to No. 8 inclusive; and in the succeeding Tables 9 and 10, the results of the former are compared, and the mean compression deduced for each 1000 lbs. of pressure applied upon a prism of each of the four classes of rock (two of slate and two of quartz), of one inch square surface, and one inch in height, and under both conditions as to the relative direction of pressure and of lamination.

* Now in the press. Chapman and Hall, London: 2 vols. 8vo.

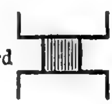
Holyhead Rock Compression.

Table I.—Experiments A, on Hard Slate; pressure transverse to lamination.

Hard  Slate.

Number of experiment.	Pressure due to the unit of surface =1 square inch.	Compression readings of the column of 0·707 inch.	Compression readings due to the successive loads.	Total compressions produced by the load on column of 0·707.	Total compressions reduced to a column of unit height=1 inch.
	lbs.	in.	in.	in.	in.
1	50	·085	·000	·000	·000
2	1,000	·081	·004	·004	·0052
3	2,000	·078+	·003+	·004	·0052
4	3,000	·078+	·003+	·004	·0052
5	4,000	·078	·003	·004	·0052
6	5,000	·078	·003	·007	·0091
7	6,000	·077+	·001+	·007	·0091
8	7,000	·077	·001	·008	·0104
9	8,000	·076+	·001+	·008	·0104
10	9,000	·076+	·001+	·008	·0104
11	10,000	·076+	·001+	·008	·0104
12	11,000	·076	·001	·008	·0104
13	12,000	·076	·001	·009	·0117
14	13,000	·075+	·001+	·009	·0117
15	14,000	·075+	·001+	·009	·0117
16	15,000	·075+	·001+	·009	·0117
17	16,000	·075	·001	·009	·0117
18	17,000	·075	·001	·009	·0117
19	18,000	·075	·001	·009	·0117
20	19,000	·075	·001	·010	·0130
21	20,000	·074+	·001+	·010	·0130
22	21,000	·074+	·001+	·010	·0130
23	22,000	·074	·001+	·010	·0130
24	23,000	·074	·001	·011	·0143
25	24,000	Crushed	·001	·011	·0143

Table II.—Experiments B, on Hard Slate; pressure parallel to lamination.

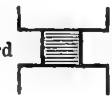
Hard  Slate.

1	50	·130	·000	·000	·0000
2	1,000	·120	·010	·010	·0130
3	2,000	·100	·020	·030	·0390
4	3,000	·099+	·001+	·031+	·0403+
5	4,000	·098	·001	·032	·0416
6	5,000	·097	·001	·032	·0416
7	6,000	·096	·001	·032	·0416
8	7,000	·094	·002	·036	·0468
9	8,000	·092+	·002+	·038+	·0494
10	9,000	·092+	·002+	·038+	·0494
11	10,000	·092+	·002+	·038+	·0494
12	11,000	·092	·002	·038+	·0494
13	12,000	·092	·002	·038+	·0494
14	13,000	·092	·002	·038+	·0494
15	14,000	·092	·002	·038+	·0494
16	15,000	·090	·002	·040	·0520
17	16,000	·089	·001	·041	·0533
18	17,000	·086	·003	·044	·0572
19	18,000	·085+	·001+	·045+	·0585+
20	19,000	·085+	·001+	·045+	·0585+
21	20,000	·085+	·001+	·045+	·0585+
22	21,000	·085	·001	·045+	·0585+

TABLE II. (*continued.*)

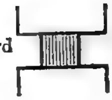
Number of experiment.	Pressure due to the unit of surface =1 square inch.	Compression readings of the column of 0·707 inch.	Compression readings due to the successive loads.	Total compressions produced by the loads in column of 0·707.	Total compressions reduced to a column of unit height=1 inch.
	lbs.	in.	in.	in.	in.
23	22,000	·085	·001	·045+	·0585+
24	23,000	·085	·001	·045+	·0585+
25	24,000	·082	·003	·048	·0624
26	25,000	·082	·003	·048	·0624
27	26,000	·080	·002	·050	·0650
28	27,000	·077	·003	·053	·0689
29	27,000+	Crushed	·003	·053	·0689

TABLE III.—Experiments C, on Hard Quartz; pressure transverse to lamination.

Hard  Quartz.

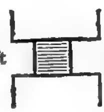
1	50	·100	·000	·000	·0000
2	1,000	·097	·003	·003	·0039
3	2,000	·095+	·002+	·003	·0039
4	3,000	·095+	·002+	·003	·0039
5	4,000	·095+	·002+	·003	·0039
6	5,000	·095+	·002+	·003	·0039
7	6,000	·095	·002	·003	·0039
8	7,000	·095	·002	·003	·0039
9	8,000	·095	·002	·005	·0065
10	9,000	·094	·001	·006	·0078
11	10,000	·093+	·001+	·006	·0078
12	11,000	·093+	·001+	·006	·0078
13	12,000	·093+	·001+	·006	·0078
14	13,000	·093	·001	·006	·0078
15	14,000	·093	·001	·006	·0078
16	15,000	·093	·001	·006	·0078
17	16,000	·093	·001	·007	·0091
18	17,000	·092+	·001+	·007	·0091
19	18,000	·092	·001	·007	·0091
20	19,000	·092	·001	·008	·0104
21	20,000	·091+	·001+	·009+	·0117+
22	21,000	·088	·003	·012	·0156
23	22,000	·083+	·005+	·012	·0156
24	23,000	·083+	·005+	·012	·0156
25	24,000	·083+	·005+	·012	·0156
26	25,000	·083	·005	·012	·0156
27	26,000	·083	·005	·017	·0221
28	27,000	·082+	·001+	·017	·0221
29	28,000	·082+	·001+	·017	·0221
30	29,000	·082+	·001+	·017	·0221
31	30,000	·082	·001	·017	·0221
32	31,000	·082	·001	·017	·0221
33	32,000	·082	·001	·018	·0234
34	33,000	·081+	·001+	·018	·0234
35	34,000	·081	·001	·019	·0247
36	35,000	·080+	·001+	·019	·0247
37	36,000	·080	·001	·020	·0260
38	36,000+	Crushed	·001	·020	·0260

TABLE IV.—Experiments D, on Hard Quartz; pressure parallel to lamination.

Hard  Quartz.

Number of experiment.	Pressure due to the unit of surface =1 square inch.	Compression readings of the column of 0·707 inch.	Compression readings due to the successive loads.	Total compressions produced by the loads in column of 0·707.	Total compressions reduced to a column of unit height=1 inch.
	lbs.	in.	in.	in.	in.
1	50	·106	·000	·000	·0000
2	1,000	·106	·000	·000	·0000
3	2,000	·106	·000	·000	·0000
4	3,000	·106	·000	·000	·0000
5	4,000	·106	·000	·000	·0000
6	5,000	·102	·004	·004	·0052
7	6,000	·100+	·002+	·004	·0052
8	7,000	·100+	·002+	·004	·0052
9	8,000	·100+	·002+	·004	·0052
10	9,000	·100	·002	·004	·0052
11	10,000	·100	·002	·004	·0052
12	11,000	·100	·002	·006	·0078
13	12,000	·098+	·002	·006	·0078
14	13,000	·098	·002	·008	·0104
15	14,000	·097	·001	·009	·0117
16	15,000	·096	·001	·010	·0130
17	16,000	·093	·003	·013	·0169
18	17,000	·092	·001	·014	·0182
19	18,000	·090+	·002+	·014	·0182
20	19,000	·090	·002	·016	·0208
21	20,000	Crushed	·002	·016	·0208

TABLE V.—Experiments E, on Soft Slate; pressure transverse to lamination.

Soft  Slate.

1	50	·088	·000	·000	·0000
2	1,000	·087	·001	·001	·0014
3	2,000	·086+	·001+	·001	·0014
4	3,000	·086	·001	·002	·0029
5	4,000	·085	·001	·002	·0029
6	5,000	·085	·001	·003	·0043
7	6,000	·079	·006	·009	·0129
8	7,000	·077+	·002+	·009	·0129
9	8,000	·077+	·002+	·009	·0129
10	9,000	·077	·002	·009	·0129
11	10,000	·077	·002	·009	·0129
12	11,000	·077	·002	·011	·0158
13	12,000	·075	·002	·013	·0187
14	13,000	·060	·015	·028	·0404
15	14,000	·050	·010	·038	·0548
16	15,000	Crushed	·010	·038	·0548

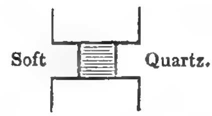
NOTE.—The cube E was 0·693 inch on the side, and the necessary reductions have been made in column 2 and subsequent ones.

TABLE VI.—Experiments F, on Soft Slate; pressure parallel to lamination.

Number of experiment.	Pressure due to the unit of surface =1 square inch.	Compression readings of the column of 0·707 inch.	Compression readings due to the successive loads.	Total compressions produced by the loads in column of 0·707.	Total compressions reduced to a column of unit height=1 inch.
	lbs.	in.	in.	in.	in.
1	50	·107	·000	·000	·0000
2	1000	·105	·002	·002	·0029
3	2000	·102+	·003+	·002	·0029
4	3000	·102	·003	·002	·0029
5	4000	·102	·003	·005	·0072
6	5000	·099	·003	·008	·0115
7	6000	·097	·002	·010	·0147
8	7000	·089	·008	·018	·0129
9	8000	·080	·009	·027	·0389
10	8000+	Crushed	·009	·027	·0389

NOTE.—The cube F was 0·693 inch on the side, and the necessary reductions have been made in column 2 and subsequent ones.

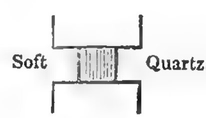
TABLE VII.—Experiments G, on Soft Quartz; pressure transverse to lamination.



1	50	·093	·000	·000	·0000
2	1,000	·093	·000	·000	·0000
3	2,000	·093	·000	·000	·0000
4	3,000	·090	·003	·003	·0043
5	4,000	·086+	·004+	·003	·0043
6	5,000	·086+	·004+	·003	·0043
7	6,000	·086	·004	·003	·0043
8	7,000	·086	·004	·007	·0101
9	8,000	·085+	·001+	·007	·0101
10	9,000	·085+	·001+	·007	·0101
11	10,000	·085	·001	·008	·0115
12	11,000	·084	·001	·009	·0129
13	12,000	·081	·003	·012	·0176
14	13,000	·068	·013	·025	·0359
15	14,000	·060	Crushed before being fully wadded.		

NOTE.—The cube G was 0·694 inch on the side, and the necessary reductions have been made in column 2 and subsequent ones.

TABLE VIII.—Experiments H, on Soft Quartz; pressure parallel to lamination.



1	50	·170	·000	·000	·0000
2	1000	·144	·026	·026	·0374
3	2000	·101+	·043+	·069	·0992
4	3000	·101	·043	·069	·0993
5	4000	·100	·001	·070	·1007
6	5000	·099	·001	·071	·1021
7	6000	·098	·001	·072	·1036
8	7000	·049	·049	·021	·1741
9	7000+	Crushed before the increased load was applied.			

NOTE.—The cube H was 0·695 inch on the side, and the necessary reductions have been made in column 2 and the subsequent ones.

TABLE IX.—Slate Rock.—Results of compression compared.—Column of unit length=1 inch.

Number of experi-ment.	Pressure in pounds on unit of surface =1 square inch.	A Hard slate across lamina.	B Hard slate with the lamina.	E Soft slate across lamina.	F Soft slate with the lamina.
	lbs.	in.	in.	in.	in.
1	50	·0000	·0000	·0000	·0000
2	1,000	·0052	·0130	·0014	·0029
3	2,000	......	·0390		
4	3,000	......	·0403	·0029	
5	4,000	......	·0416	......	·0072
6	5,000	·0091	......	·0043	·0115
7	6,000	......	......	·0129	·0147
8	7,000	·0104	·0468	......	·0259
9	8,000	......	·0494	......	·0389
10	9,000	......	......	......	Crushed
11	10,000				
12	11,000	......	......	·0158	
13	12,000	·0117	......	·0187	
14	13,000	......	......	·0404	
15	14,000	......	......	·0548	
16	15,000	......	·0520	Crushed	
17	16,000	......	·0533		
18	17,000	......	·0572		
19	18,000	......	·0585		
20	19,000	·0130			
21	20,000				
22	21,000				
23	22,000				
24	23,000	·0143			
25	24,000	Crushed	·0624		
26	25,000				
27	26,000	......	·0650		
28	27,000	......	·0689		
29	28,000	......	Crushed		
30	29,000				
Mean compression for each 1000 lbs. on unit of surface		in. ·0006217 up to 23,000 lbs.	in. ·0025000 up to 26,000 lbs.	in. ·0039144 up to 14,000 lbs.	in. ·0037000 up to 7000 lbs.

TABLE X.

Quartz Rock.—Results of compression compared.—Column of unit length=1 inch.

Number of experi-ment.	Pressure in pounds on unit of surface =1 square inch.	C Hard quartz across lamina.	D Hard quartz with the lamina.	G Soft quartz across lamina.	H Soft quartz with the lamina.
	lbs.	in.	in.	in.	in.
1	50	·0000	·0000	·0000	·0000
2	1000	·0039	......	......	·0374
3	2000	......	......	......	·0992
4	3000	......	......	·0043	·0993
5	4000	......	......	......	·1007

TABLE X. (*continued.*)

Number of experiment.	Pressure in pounds on unit of surface =1 square inch.	C Hard quartz across lamina.	D Hard quartz with the lamina.	G Soft quartz across lamina.	H Soft quartz with the lamina.
	lbs.	in.	in.	in.	in.
6	5,000	......	·0052	......	·1021
7	6,000	......	......	......	·1036
8	7,000	......	......	·0101	·1741
9	8,000	·0065	......	......	Crushed
10	9,000	·0078			
11	10,000	......	......	·0115	
12	11,000	......	·0078	·0129	
13	12,000	......	......	·0176	
14	13,000	......	·0104	·0359	
15	14,000	......	·0117	Crushed	
16	15,000	......	·0130		
17	16,000	·0091	·0169		
18	17,000	......	·0182		
19	18,000				
20	19,000	·0104	·0208		
21	20,000	·0117	Crushed		
22	21,000	·0156			
23	22,000				
24	23,000				
25	24,000				
26	25,000				
27	26,000	·0221			
28	27,000				
29	28,000				
30	29,000				
31	30,000				
32	31,000				
33	32,000	·0234			
34	33,000				
35	34,000	·0247			
36	35,000				
37	36,000	·0260			
38	37,000	Crushed			
Mean compression for each 1000 lbs. on unit of surface		in. ·0007085 up to 35,000 lbs.	in. ·0010947 up to 19,000 lbs.	in. ·0014666 up to 12,000 lbs.	in. ·0172666 up to 6000 lbs.

An examination of these Tables presents some remarkable and, so far as I am aware, now for the first time observed results.

As might have been expected, the quartz-rock is much less compressible generally than the slate-rock, with this exception, however, that the softest specimens of quartz-rock, and those alone, are much more compressible than the softest slate, when both compressed in the direction of or parallel to the lamination.

In this direction of compression, the hardest slate is more than double as compressible as the hardest quartz.

When compressed transverse to the lamina, however, the hard slate and hard quartz prove to have very nearly the same coefficient of compressibility, which is very small for both; while the softest slate and the softest quartz, compressed in the same way (transverse to lamina), have also nearly the same coefficient of compressibility, but one about four times as great as for the hardest like rocks.

These facts point towards the circumstance of the original deposit and formation of these rocks as their efficient causes. Both rocks consist of particles more or less wedge-shaped and flat, and angular fragments more or less crystalline, deposited together, with their larger dimensions in the planes of lamination, which lamination has been produced by enormous compression in a direction transverse to its planes. Hence the mass of these rocks has already been subjected to enormous compression in the same direction as that in which we now find their further compressibility the least. But, besides that we might from this cause alone anticipate a higher compressibility when the pressure is applied to them parallel to the lamination, another condition comes into play: their aggregation of flat, wedge-shaped particles, when thus pressed edgeways, tends powerfully to their mutual lateral expansion, and hence to their giving way in the line of pressure.

The *per-saltum* way in which all the specimens of both rocks yield, in whatever direction pressed, is another noteworthy circumstance. On examining the Tables I. to VIII., it will be seen that the compressions do not constantly advance with the pressure, but that, on the contrary, the rock occasionally suffers almost no sensible compression for several successive increments of pressure, and then gives way all at once (though without having lost cohesion, or having its elasticity permanently impaired) and compresses thence more or less for three or four or more successive increments of pressure, and then holds fast again, and so on. This phenomenon is probably due to the mass of the rock being made up of intermixed particles of several different simple minerals, each having specific differences of hardness, cohesion, and mutual adhesion, and which are, in the order of their resistances to pressure, in succession broken down, before the final disruption of the whole mass (weakened by these minute internal dislocations) takes place.

Thus it would appear that the micaceous plates and aluminous clay-particles interspersed through the mass give way first. The chlorite in the slate, and probably felspar-crystals in the quartz-rock, next, and so on in order, until finally the elastic skeleton of silex gives way, and the rock is crushed. It is observable, also, that this successive disintegration does not occur at equal pressures, in the same quality and kind of rock, when compressed transverse and parallel to the lamination. It follows from this constitution of these (and probably of all) rocks that very different powers of transmitting wave-impulses must arise when the originating forces vary considerably in amount produced of primary compression. It is almost superfluous also to point out the great differences in wave-transmissive power in directions transverse and parallel to lamination that these experiments disclose. They prove to us that, in an earthquake shock of given original power, the vibrations will have the largest amplitude when transmitted in the line of lamination, but may be propagated with the greatest velocity in directions transverse to the same, *assuming in both cases the rock solid and unshattered.*

In Table XII. the general results are deduced, and the mean compressions for each of the rocks calculated, and finally the moduli of elasticity are obtained, in pounds and in feet; the specific gravities adopted in calculating the latter being those given in the body of the paper, as follows:—

TABLE XI.

		Weight of a prism 1 foot long and 1 inch square.
	sp. gr.	lbs.
Hardest Slate	2·763	1·1992
Softest Slate	2·746	1·1918
Hardest Quartz	2·656	1·1528
Softest Quartz	2·653	1·1515
Mean for Slate	2·7545	1·1955
Mean for Quartz	2·6545	1·1522
General mean for both rocks	2·7045	1·1739

Holyhead Rock Compression.—Table XII.

General results reduced, Modulus of Cohesion and of Elasticity, &c.—Slate and Quartz.

No.	Class of Rock, and direction of pressure in relation to structure.	Coefficient of compression on unit surface for 1000 lbs.	Elastic limit for compression.	Crushing load on the unit of surface.	Modulus of cohesion (compression).	Modulus of elasticity.	Modulus of elasticity. L.	Coefficient T_r.
		in.	lbs.	lbs.	feet.	lbs.	feet.	
1	Slate, *hardest across* lamination	·0006217	22,000	24,000	20,014	8,042,464	6,706,524	1·2432
2	Quartz, *hardest across* lamination	·0007085	32,000	37,000	32,095	7,057,163	6,121,758	2·1830
3	Slate, *hardest parallel to* lamination	·0025000	18,000	27,000	22,515	2,000,000	1,667,778	5·6241
4	Quartz, *hardest parallel to* lamination	·0010947	17,000	20,000	17,349	4,567,461	3,962,013	1·8240
5	Slate, *softest across* lamination	·0039144	12,000	15,000	12,586	1,277,335	1,071,769	4·8930
6	Quartz, *softest across* lamination	·0014666	11,000	14,000	12,158	3,409,246	2,960,699	1·7108
7	Slate, *softest parallel to* lamination	·0037000	6,000	9,000	7,552	1,351,351	1,133,874	2·7747
8	Quartz, *softest parallel to* lamination	·0172666	7,000	8,000	6,948	289,576	251,477	11·6112
	Calculated means.							
9	Slate, mean for *hard and soft across* lamination	·0022680	17,000	19,500	16,311	2,204,585	1,844,069	3·6855
10	Quartz, mean for *hard and soft across* lamination	·0010875	16,500	25,500	22,132	4,597,701	3,990,455	2·3103
11	Slate, mean for *hard and soft parallel to* lamination	·0031000	12,000	18,000	15,056	1,612,903	1,349,145	4·6494
12	Quartz, mean for *hard and soft parallel to* lamination	·0091806	12,000	14,000	12,151	544,627	472,684	10·7100
	Calculated mean of means.							
13	Slate, hard and soft, mean for both directions (Nos. 9 and 11)	·0026840	14,500	18,750	15,684	1,862,880	1,566,541	4·1914
14	Quartz, hard and soft, mean for both directions (Nos. 10 and 12)	·0051340	16,750	19,750	17,141	973,899	845,252	8·4490
15	General mean for slate and quartz, hard and soft, and in both directions (Nos. 13 and 14)	·0039090	15,625	19,250	16,398	1,279,099	1,089,615	6·2697

In Table XII. the load on the unit of surface (1 square inch) at which the elastic limit of the rock is passed, and that at which it is finally crushed, together with the modulus of cohesion or resistance to compression, are also given, and will be useful to the engineer and architect. In the last column, the value of my own modification of Poncelet's coefficient T_r (la force vive de rupture) is calculated in foot pounds, and represents the relative work done at fracture in each case.

To apply the results thus obtained to those of experimental wave-transmission at Holyhead.

Poisson has shown (Traité de Mécanique, vol. ii. p. 319) that the velocity of wave-transmission (sound) in longitudinal vibrations of elastic prisms is

$$V^2=\frac{glq}{p}. \quad \text{(I.)}$$

When g has its usual relation to gravity, l and p are the length and weight of the prism, and $q=\frac{\Delta}{\delta}$, Δ being a weight that is capable of elongating the prism by an amount$=\delta l$, or extending it to the length

$$l(1\times\delta).$$

Substituting, we have

$$V^2=\frac{gl\Delta}{p\delta};$$

but $\Delta : W :: \delta : 1$, W being the weight capable of doubling the length of the prism. Therefore

$$V^2=\frac{glw\delta}{p\delta}=\frac{gl\mathrm{L}}{l}=g\mathrm{L},$$

$$\text{or } V=\sqrt{g\mathrm{L}}. \quad \text{(II.)}$$

So that L being the modulus of elasticity of the solid, expressed in feet, the velocity of wave-transmission through it, if absolutely homogeneous and unbroken, is

$$V=5{\cdot}674\sqrt{\mathrm{L}}. \quad \text{(III.)}$$

Where, owing to want of homogeneity, or to shattering, or other such condition, as found in natural rock, the experimental value of V differs from the above theoretic one, we may still express the former by the same general form of equation—

$$V'=\alpha\sqrt{\mathrm{L}}, \quad \text{(IV.)}$$

in which the coefficient α expresses the ratio to g that the actual or experimental bears to the theoretic (or maximum possible) velocity of wave-transmission.

In the slate- and quartz-rocks of Holyhead, I ascertained the mean *lowest* velocity of wave-transmission (for small explosions or impulses) to be 1089 feet per second (omitting decimals), the mean *highest* velocity 1352 feet per second, and the *general mean* velocity from all, 1220 feet per second.

Applying Eq. IV. to these numbers, and adopting the values of L given in Table XII. (mean of Nos. 9 and 10), we obtain

$$\alpha=\frac{V'}{\sqrt{\mathrm{L}}};$$

and for the three preceding velocities, α has the following values:—

$$1 \ldots V'=1089 \ldots\ldots \alpha=\frac{1089}{\sqrt{2917262}}=\frac{1089}{1708}=0{\cdot}637$$

$$2 \ldots V'=1352 \ldots\ldots \alpha=\frac{1352}{\sqrt{2917262}}=\frac{1352}{1708}=0{\cdot}791$$

$$3 \ldots V'=1220 \ldots\ldots \alpha=\frac{1220}{\sqrt{2917262}}=\frac{1220}{1708}=0{\cdot}714$$

The actual velocity of wave-transmission in the slate and quartz together, therefore, was to the theoretic velocity due to the solid material as

$$\alpha : \sqrt{2g} \text{ or } 0{\cdot}714 : 5{\cdot}674, \text{ or } 1{\cdot}00 : 7{\cdot}946.$$

From which it results, that nearly *seven-eighths* of the full velocity of wave-transmission due to the material is lost by reason of the heterogeneity and discontinuity or shattering of the rocky mass, as it is found piled together in nature.

This loss would be proportionately larger with still smaller originating impulses, and *vice versâ,* but in what proportion we are not at present in a position to know.

If we may for a moment allude to final causes, we cannot but be struck with this beneficent result (amongst others) arising from the shattered and broken-up condition of all the rocky masses forming the habitable surface of our globe, viz. that the otherwise enormous transit-velocity of the wave-form in earthquake shocks is by this simple means so reduced.

That this retardation is mainly effected by the multiplied subdivisions of the rock, and in a very minor degree by differences in the elastic moduli of rock of different species, is apparent on examining the Tables IV. and V. of the previous part of this Report referring to the experiments at Holyhead.

Although, therefore, we are now enabled, from what precedes, to calculate values for α, for the slate rocks and for the quartz of Holyhead, separately, and thus obtain separate values for V', for *each* of those rocks; the result would probably be more or less delusive, as we have no possible means of deciding what is the relative amount of shattering and discontinuity for equal horizontal distances, in each of these two rocks; nor what the relative retarding powers, of planes of separation running in variable directions, and at all possible angles, across the line of wave-transit, as compared with their retarding powers, if either all transverse to, or all in the same direction as, the wave-path.

The greatest possible mean velocity of wave-propagation, *in rock as perfectly solid and unshattered as our experimental cubes,* is determinable for both slate and quartz in the two directions of transmission, viz. transverse to and in the line of lamination, from Eq. III., and the mean values of L in Nos. 9 and 10, and 11 and 12, Table XII., as follows:—

		ft. per sec.
Mean of slate and quartz transverse to lamination.	$V=5{\cdot}674\sqrt{2917262}$	$=9691$
Mean of slate and quartz in line of lamination	$V=5{\cdot}674\sqrt{910914}$	$=5415$,

both in round numbers; or the transverse is to the parallel transit-rate nearly as $1{\cdot}8 : 1{\cdot}0$.

This great difference of velocity, due to the difference in the molecular properties of *the material* of the rocks in their opposite directions, is, as our Holyhead experiments prove, almost wholly obliterated by the vastly increased degree of discontinuity and shattering, in the directions approaching that of lamination, or transverse to the wave-path in the first case.

It is necessary to guard against any misconception as to the import of this result. The fact ascertained and just enunciated is this, that the velocity of wave-transmission is greater in *the material of these rocks* in a direction across their lamination than in one longitudinal to the same, provided or *assuming the material be perfectly unshattered in both*—as homogeneous, in fact, as the small specimen-cubes experimented upon. And were the whole mass of the rock, as it lies in the mountain-bed, as homogeneous as such cubes, then the velocity of wave-transmission would *actually* be greater *across* long ranges of natural lamination, than edgeways to them. The opposite, however, is often the case; the wave-transit period is slower as the range of rocky mass is more shattered, discontinuous and dislocated.

These conditions most affect rocks in nature in or about their planes of bedding, lamination, &c., and hence most retard wave-impulses transverse to these planes; so that *the more rapid wave-transmissive power of the material of the rock in a direction transverse to the lamination may be more than counterbalanced by the discontinuity of its mass transverse to the same direction.*

The results of Wertheim, on the transmission of sound in timber, proved the velocity to be greatest in a direction longitudinal to the fibres and annual layers of wood; less in a direction perpendicular to the same, and radially outwards from the centre of the tree towards its exterior; and least of all in a direction, *quam prox.*, parallel to the annual rings, and perpendicular to the longitudinal fibres; that is to say, in each case the velocity of sound was rapid in proportion to the less compressibility of the wood in the same direction. His results might seem at first to conflict with those which I have announced. Any such conclusion, however, would be a mistake; on the contrary, my results perfectly analogize with those above alluded to. The difference between the cases is, that wood in mass, however large, is practically homogeneous and unshattered, and that *its direction of least compressibility is longitudinal to its laminæ* (or annual layers); whereas *the direction of least compressibility of rock is transverse to its laminæ* which have been already powerfully compressed in this direction. In fact, as respects the question here in point, there is no true analogy in *structure* between the lamination (by annual rings) of wood, and the lamination or bedding of rock.

It follows from what precedes, that earthquakes and rocks, as both actually occur in nature,—the rocks being of a stratified or laminated form (generally all sedimentary rocks),—must present the following conditions as to rate of transit of shock:—

1st. If such rocks were perfectly unshattered, and the beds or laminæ in absolute contact, the shock would be transmitted more rapidly across these than in their own direction.

The difference is more in favour of the transverse line, in proportion as the rock is made up more of angular sedimentary particles of very unequal dimensions, the longest being parallel to the general lamination, and in proportion as the imbedding paste is softer in relation to such particles.

Some sedimentary rocks no doubt exist, made up of particles perfectly uniform and equal in all three dimensions, and without imbedding paste—such as the lithographic stones of Germany, the Apennine marl-beds, &c., in which (assuming the above condition as to continuity) the transit-period would be alike in all directions probably.

2nd. The actual amount of shattering and discontinuity in nature being usually greatest, upon the whole, in planes parallel to bedding or lamination, the transit-rate of shock is most generally fastest in the line of the beds or lamination, rather than across them.

Or, at least, this latter condition may interfere with the former to the extent of partial, complete, or more than complete obliteration.

I am not aware that any experiments have previously been made upon the compressibility, &c., of the slate- and quartz-rocks of Holyhead; and as these rocks are being employed there upon a vast scale for submarine building works, it may not be out of place to draw a few conclusions of a character useful to the practical engineer from the data that have been obtained. Some conclusions may be drawn which are applicable to all classes of laminated rocks in the hands of the engineer.

It is a very prevalent belief that slate-rock (for example), in the form of the sawed roofing-slate of Anglesea or of Valentia (Ireland), will bear a much greater compressive load when the pressure is in the direction of the laminæ, than in one across them. This the preceding experiments prove to be wholly a mistake—one that has very probably arisen from some vague notion of an analogy with timber compressed the end-way of the grain.

It is now certain that Silurian slates and quartz-rock, and probably all sedimentary laminated rocks, whether with cleavage or not, are much weaker to resist a crushing force edgeways to the lamina, than across the same, and that the range of compressibility is much greater, for equal loads, in the former direction.

The facts now ascertained as to the great relative compressibility of laminated rock in the direction of the laminæ also points out the reason of the great bearing power to sustain impulsive loads, which the toughest and most cohesive examples of slate-rocks, such as the slates of Caernarvonshire, present; for there can be no grounds to doubt that the high *compressibility* of rocks of this structure in the plane of the lamina is also accompanied with a high coefficient of *extensibility*, although probably confined within much narrower limits as to inceptive injury to perfect continuity.

My experiments point out, that the Silurian slate of Holyhead (the mean both of the hard and the soft) is crushed by a load *across the lamina* of about 1250 tons per square foot, and that its molecular arrangement is permanently injured at a little more than 1000 tons per square foot.

The quartz-rock (the mean of both hard and soft) is crushed by a load, applied in the same manner, of 1630 tons per square foot, and its molecular arrangement is permanently injured at less than 1000 tons per super foot. The quartz-rock gives the highest measure of ultimate resistance, but it is the less trustworthy material when loaded heavily.

Neither of these sorts of rock, if loaded so as to be pressed *in the direction of the lamina*, would sustain more than about 0·7 of the above loads at the crushing-point and at that of permanent injury, respectively. From the extreme inequality found within narrow limits in both rocks as quarried, neither should be trusted for safe load in practice with more than about $\frac{1}{20}$th of the mean load that impairs their molecular arrangement, as ascertained from selected specimens, or (say) not to more than 50 tons per square foot for passive or 25 tons per square foot for impulsive loads.

The high relative compressibility of laminated rocks in the direction of the lamina might probably be made advantageous use of, where they are employed as a building material, for the construction of revetment or other walls of batteries exposed to the stroke of cannon shot, by building the work (under suitable arrangements to obviate splitting up) with the planes of the laminæ in the direction of the line of fire, *i. e.* perpendicular to the faces of the work; for on inspecting the last column in Table XII. which contains the values of T_r under the several conditions of rock and of compression, it is at once apparent how much greater is the "work done" in crushing the slates and the quartz in their toughest and most compressible direction, *i.e.* in the direction of the lamina. *Twice as much work* is, upon the average, consumed in crushing the rock in this direction, that suffices to destroy its cohesion in the one transverse to the lamina; and the proportion in the two, in the case of the softest quartz (Nos. 5 and 8), is as much as about *five to one.*

It would be unsuitable, however, to the present memoir to pursue further here such practical deductions suggested by the results obtained experimentally.

On the Explosions in British Coal-Mines during the year 1859. *By* THOMAS DOBSON, *B.A., Head Master of the School Frigate "Conway," Liverpool.*

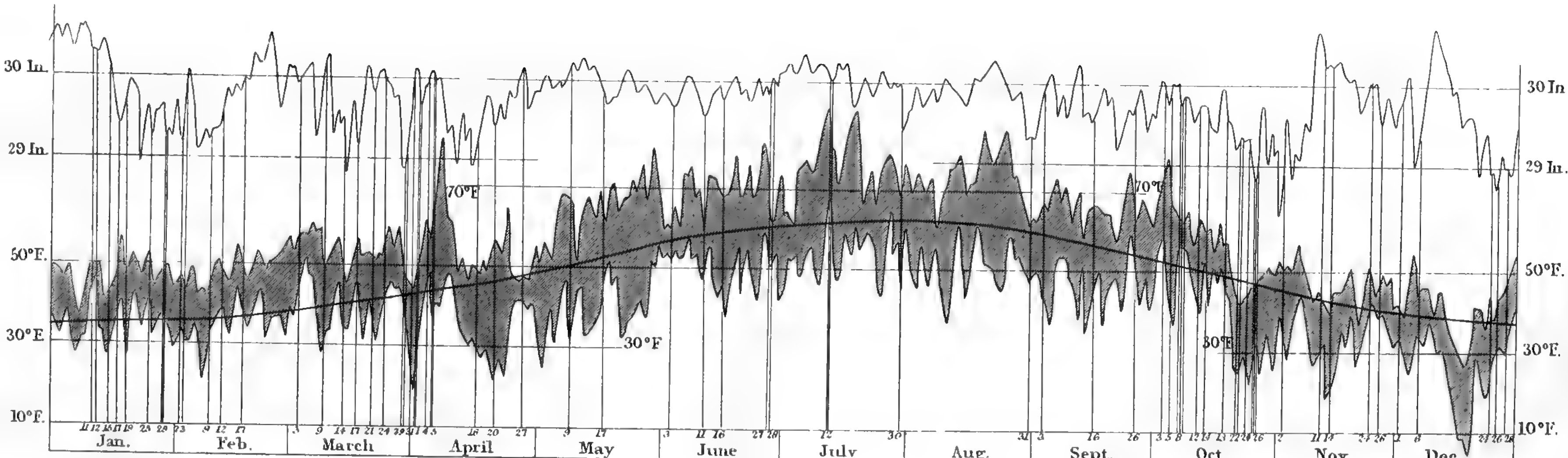
IN my Report "On the Relation between Explosions in Coal-mines and Revolving Storms," read at the Meeting of this Association, at Glasgow, in 1855, I have given my reasons for thinking that the freedom of the atmosphere of a mine from noxious gases, and the occasional abundant issue of such gases into a mine, are in a great measure dependent upon certain conditions of the pressure and temperature of the external atmosphere. This dependence is, indeed, a consequence so direct and obvious of the first principles of pneumatics, that we may speak with certainty of the *kind* of influence exerted by the atmosphere in restraining or augmenting the flow of inflammable gases into a mine; and we have only to inquire whether this influence is ever exercised to such a *degree* as to charge a mine up to the point of explosion.

It is, I think, now generally admitted that a high atmospheric pressure tends to check the issue of gases into the workings of a mine, and that a low pressure favours their copious effusion from the broken coal and deserted goaves.

It is also evident that a low temperature of the external air makes the ventilation of a mine brisk and effective, while a high temperature of the air above renders the ventilation sluggish, and causes the gases to accumulate below.

I have compared the dates of all the fatal explosions in British coal-mines, as given in the Reports of the Government Inspectors of Mines, with the corresponding barographical and thermographical records for several years, and find that this comparison tends to confirm in a very striking manner the conclusions arrived at in my Report of the year 1855.

Were the Government Inspectors to give in their Reports the dates of *all* explosions of gases in mines, whether fatal or not, and also the dates of days when mines have been in a dangerous state from the abundance of gas, but explosion avoided, the evidence of atmospheric influence would soon be placed beyond doubt. Seeing that the great atmospheric disturbances with which we are here concerned generally extend nearly simultaneously over Britain and the adjacent countries of the Continent, I have been at some pains to obtain the dates of all the great explosions in the coal-mines of France and Belgium; but I was told at the École des Mines, in Paris, that they had no



Thos. Dobson

J.W. Lowry fc.

such record, and a communication with the director of the mines of Belgium was also fruitless.

The dates for the year 1859 of all the fatal explosions in the coal-fields of England, Scotland, and Wales are marked in the meteorological diagram (Plate V.), in which one day is represented by a horizontal space of one-twentieth of an inch, and 20° Fahr. by a vertical height of one inch.

For the meteorological data I am indebted to the kindness of Mr. Milner, the surgeon of Wakefield Prison, where the instruments are read every six hours, night and day. The portion of the diagram for the months of October and November, showing the state of the atmosphere during the passage of the 'Royal Charter' storm, has been compared with observations made at Oxford, Kew, Stonyhurst College, Lancashire, and the Bishop's-rock Lighthouse, Scilly Isles; and the general agreement fully warrants the selection of the Wakefield curves as a fair type of the state of our atmosphere during the year 1859.

The curve of mean temperature is from results in a paper by Mr. Glaisher in the 'Transactions of the Royal Society' for 1850.

If there were no connexion whatever between the weather and the conditions that favour an explosion in a coal-mine, it would be found that the 70 or 80 vertical lines that denote fatal explosions would be scattered, as if by chance, over the whole diagram, without any apparent reference to the great depressions in the barometric curve, or to the great and sudden rises in the thermometric curve. But this is not the case in any of the years that I have examined. On the contrary, it is found that the lines of explosion have a very decided tendency to group themselves about the few great atmospheric perturbations of each year; and to leave a very conspicuous and highly significant blank in spaces, of a whole month's duration occasionally, where the pressure has been uniformly high and the temperature moderate.

In the 68 explosions of 1859 are found three dense groups and a number of equally instructive blanks.

The first group falls between the 11th of January and the 17th of February, during which period the diagram shows that even the nocturnal temperature was considerably above the mean daily temperature, and the barometric curve exhibits a succession of deep indentations marking the passage of a series of storms.

The dates and localities of the explosions forming this group are:—

January 11, Bewdley.
——— 12, Atherstone.
——— 15, Huddersfield.
——— 17, Ayr, Scotland.
——— 19, Wigan.
——— 25, Stevenston, Scotland.
——— 29, Burslem, Staffordshire.
January 29, Aberdare, S. Wales.
February 2, Dudley.
——— 3, Coatbridge, Scotland.
——— 9, Willenhall.
——— 12, Wednesbury.
——— 17, Wigan.

Two cases of death from suffocation by gas fall within this group, viz.,—

On February 1, at St. Helen's, and
——— 18, at Tiviotdale, Rowley Regis.

An interval of a fortnight follows, with a high atmospheric pressure, and no fatal accidents in mines from gas.

During March, and the first week of April, the temperature is far above the mean, and two well-characterized cyclones send the mercury in the barometer at Wakefield down to 28·83 on the 14th, and to 28·91 on the 28th.

The second great group of 14 explosions falls in this interval; 8 explosions happening within 8 consecutive days—exactly coinciding with one of the greatest disturbances both of pressure and temperature during the whole year. The dates are:—

March 3, Fenton.	March 29, Dudley.
—— 9, Framwellgate, Durham.	—— 31, St. Helen's, Lancashire.
—— 14, Whiston, Lancashire.	April 1, Congleton.
—— 17, Sheffield.	—— 1, Merthyr.
—— 21, Wrexham.	—— 4, Kilmarnock.
—— 24, Coatbridge, Scotland.	—— 5, Hilda, Durham.
—— 29, Hopton, Manchester.	—— 5, Leeds.

A miner was suffocated by gas at Aberdare on the 3rd of March.

No more great groups occur until October; but there is scarcely a single explosion that does not point to atmospheric influences, and in some cases in a very unmistakeable manner, as those of the 27th and 28th June, after the maximum thermometer had marked 81° F. and 80°·75 F. on the two preceding days, and the minimum thermometer showed 57°·25 F. and 58°·25 F.; and the two explosions on the 12th July, the maximum thermometer having marked 85°·25 F. and 90° F., and the minimum thermometer 52°·25 F. and 67°·50 F. on the two preceding days. It will also be observed that there is an entire absence of explosions from July 30 to August 31, a period of high atmospheric pressure and mean temperature.

The dates of explosions from April 5 to the end of September are:—

April 16, Holywell. N. Wales.	June 28, Wigan, Lancashire.
—— 20, Wakefield.	July 12, St. Helen's, Lanc.
—— 27, Aberdare.	—— 12, Wakefield.
May 9, Airdrie, Scotland.	—— 30, Tollcross, Scotland.
—— 17, Pendleton, Manchester.	Aug. 31, Stevenston, Scotland.
June 3, Nantyglo, Wales.	Sept. 3, Walsall.
—— 11, Church, Manchester.	—— 16, Tipton.
—— 16, Bilston.	—— 26, Radcliffe, Manchester.
—— 27, Tredegar, Wales.	

The dates of fatal accidents from suffocation by gas during this period are:—

May 18, Bathgate, Scotland.	July 8, Halifax.
July 5, Chesterton.	Aug. 16, Aberdare.

In the beginning of October the temperature was unusually high, even the minimum thermometer ranging above the mean for several days. On the 7th and 8th the reading of the minimum thermometer at Wakefield was 56° F., and three fatal explosions happen on the latter day. On the 18th began a remarkable atmospheric paroxysm which lasted until the 10th of November, and of which the 'Royal Charter' storm, on the 26th October, was only a portion. During this interval there were lost by shipwreck on the British coasts 877 lives and 77 vessels. On the very day that the 'Royal Charter' steamship was lost in a violent storm, there occurred three fatal explosions, two in England and one in Scotland.

The October group contains 14 explosions, to which may be added 4 cases of death from suffocation by gas, of which the respective dates and localities are:—

Oct. 3, Walsall.	Oct. 8, Robert's Town, Leeds.
—— 5, Seacroft, Leeds.	—— 12, Newport, Shropshire.
—— 7, Dudley (suffocation).	—— 14, Aberdare, South Wales.
—— 8, Prescot, St. Helen's.	—— 14, Heaton, Northumberland (suffocation).
—— 8, Pendlebury, Manchester.	

Oct. 17, Groveland Pit, Rowley Regis (suffocation).
—— 18, Tiviotdale Pit, Rowley Regis.
—— 20, Hampstead (suffocation).
—— 22, Dean Hall, Leeds.
Oct. 22, Washington, Durham.
—— 24, N. Bitchburn, Crook.
—— 26, Tipton.
—— 26, Longton.
—— 26, Tollcross, Scotland.

It is instructive to compare this group of accidents in October, when the atmospheric conditions were highly favourable to the presence of inflammable gases in coal-mines, with the entire blank shown by the diagram in August, when the atmospheric conditions were as decidedly of an opposite tendency.

The only fatal accidents from gas in mines during November and December were by explosions, thus:—

Nov. 2, Royton, Manchester.
—— 11, Donnington.
—— 14, Dukinfield.
—— 24, Royton, Manchester.
—— 26, Wakefield.
Dec. 1, Burton-on-Trent.
—— 6, Walker.
—— 24, Atherton.
—— 26, Ormskirk, Lancashire.
—— 28, Leeds.

Continuation of Report on Steam Navigation at Hull. By JAMES OLDHAM, *C.E., Member of the Institution of Civil Engineers.*

IN 1853, when I made my first Report to the British Association on the rise and progress of steam navigation at Hull, we had twenty-one sea-going and twenty-three river steamers; now we have sixty-six sea-going and twenty-five river steamers belonging to the port.

There are also belonging to places on the waters of the Humber, more or less, but chiefly trading with our port, twenty-six steam-vessels of different kinds, and there are about twenty to twenty-three steam-ships belonging to other English ports and foreign states regularly trading to Hull, giving a total of about 140 in one way or other using the port of Hull; while in 1853 the total fleet of every class and country amounted to eighty-one, giving an increase of fifty-nine.

Notwithstanding the many losses and changes which have occurred amongst our steam-vessels since my Report at Aberdeen two years ago, I am enabled to say that we never possessed so numerous and so fine a fleet as at the present time,—a fleet which, for efficiency and seaworthiness, may compare, tonnage for tonnage, with any other port.

It is not, however, the number of steam-ships connected with the port that is the true criterion on which to judge of an advance or otherwise, but the amount of tonnage of actual business performed on which we can draw true conclusions; and I find as a proof, that while in 1840 the gross tonnage (steam and sailing) on which dock dues were paid amounted only to 652,508, in 1852 it had reached 799,866, and in 1860 it had attained 1,215,203 tons; and while the actual steam tonnage in 1840 only amounted to 174,832, in 1852 it had reached 305,021, and in 1860 it was found to be 603,328, having within a fraction doubled in eight years. And what is still more remarkable is, that although steam is fast taking the lead, and has so wonderfully advanced, the sailing-ship tonnage has also in a most astonishing ratio increased; for in 1840 this class of tonnage amounted to 477,676, in 1852 to 494,845, and in 1860 to no less than 611,875 tons.

The above statements of tonnage relate solely to inward traffic, and not outward.

These facts not only justify the Dock Company in the steps they are now taking to extend the dock-space and wharfage-accommodation so imperatively demanded, but will show the necessity of still further providing for the great increase of space which, from the rapidly growing trade, and the increase in number and size of our steam-ships, we may fairly anticipate will shortly be wanted.

To check and hold back the supply of necessary water-space is to produce a retrograde effect; and not to meet the wants of the port is to encourage any rivals who may be ambitious enough to attempt to take our trade from us.

Great inconvenience has long been felt by steam-ship owners for want of more extended accommodation. At present the total area of the dock is under 43 acres for the whole of the shipping; but to give the facilities required it ought to be double that amount. An extension of 17 acres is, however, at once to be added to the present space in the construction of the Western Dock, specially for the steam-shipping, in addition too of an enlarged entrance tidal basin to be common to the Humber and Western Docks.

Let therefore the Dock Company be true to its own real interests and those of the port at large, and long delays and expensive conflicts in obtaining the necessary accommodation for the rapidly increasing fleet of steamers will no longer be known and felt, and Hull, which has long held the proud position of the third British port, will still continue to maintain that honourable post.

With the young and vigorous new blood recently imported into the directory of the Company, and with its active, talented, and enterprising officers at the head of its executive, the port asks for and expects extension of dock-space and every modern and improved appliance, to facilitate all the varied operations, and to meet liberally all its rapidly growing wants.

I have only to add that during the last ten years upwards of 120 steam-ships have been built and equipped at the port of Hull, several of which are from 1000 to 3000 tons burthen, reflecting the highest credit both on the builders as well as on the port.

Austrian Chambers, Hull, August 1861.

Brief Summary of a Report on the Flora of the North of Ireland. By Professor G. Dickie, *M.D.*

The district to which the Report refers comprehends that part of Ireland which lies to the north of a line passing to the west from Dundalk, embracing ten entire counties and part of other two.

The information respecting the native flora of this district has been derived mainly from the following sources:—Dr. Mackay's 'Flora of Ireland;' a valuable list contributed by D. Moore, Esq., of the Glasnevin Botanic Garden; notes contributed by Mr. Hyndman, of Belfast; the MSS. of the late Mr. Templeton, of Cranmore, liberally placed at my disposal by Mrs. Templeton; and lastly, records of species observed by myself during excursions to different parts of the north of Ireland.

Details will be given in the full Report for insertion in the next volume of the Transactions of the Association.

It will be sufficient here to give a summary of the results. The standard adopted is the 'British Flora,' by Sir W. J. Hooker and Prof. Arnott; and in order to bring out the botanical features of the district, the types of Mr. Watson (in his 'Cybele Britannica') afford the best means for comparison.

The total number of species of Phænogams in the district may be estimated at 725. In the entire flora of the United Kingdom, those of the English type are 396, the Scottish 68, Highland 108, Germanic 196, Atlantic 60. In the district there are 166 of the English type, 39 Scottish, 22 Highland, 17 Atlantic, and 3 only of the Germanic type; the remainder of course embracing those of general occurrence in Britain, hence called the British type.

The flora therefore is characterized by a large admixture of species belonging to the English and Scottish types, with a fair proportion of those called Western or Atlantic; the number of Highland species is small, as might have been expected, owing to the physical characters of the country; those of the Germanic type are still fewer, only three out of 196 British species being referred to that type.

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. By Professor Owen, *F.R.S. &c.*

[A communication ordered to be printed among the Reports.]

The Andaman Islands extend from 10° 32′ to 13° 10′ N. lat., and are situated in 92° 30′ E. long.: they are divided into Great and Little; the former, consisting of three islands, called North, Middle, and South Andamans, are so closely contiguous as to form one tract of 140 miles long, and not more than 20 miles across the greatest breadth, having a surface of 2800 square miles, and inhabited by a race of undersized or dwarf blacks, notorious for their audacity and implacable hostility to all strangers. The skin is of a sooty darkness; the hair of the head black, crisp, apparently short, and growing in small detached tufts; the nose is broad, short, and rather flat, but not particularly widened at the end, with the expanded nostrils of the Guinea negro; the lips are thick, but less prominent than in the Guinea negro: they are said to shave off or eradicate the hair of the face, except the eyelashes; it is doubtful, at least, whether naturally they are devoid, as they appear, of beard, moustaches, and whiskers. The hands and feet are small; but the heel does not project, as in some African negroes.

The following notices of the habits and manners of the Mincopies, or natives of the Andamans, are condensed from the "Reports" of the able Superintendents and Surveyors of the convict settlements recently established by the East Indian Government on these islands; particularly from the statement of a Brahmin Sepoy, one of the transported mutineers, who, after escaping from the convict establishment, passed upwards of a year (from April 23, 1858, to May 17, 1859) with a tribe of Andamaners*. His statement accorded with previous accounts, that the diminutive aborigines of these islands have no notions of a Deity or a future state; that both sexes go naked.

They generally inhabit the jungle along the sea-coast; but are migratory, rarely residing many days in one spot. They are divided into parties of from twenty to three hundred, including the usual proportion of males and females, adults and children; all having similar features, colour of skin and eyes, the same language, habits, and customs. After puberty, the females have promiscuous sexual intercourse, save with their own father, until they are chosen or allotted as a wife, when she is required to be faithful to her hus-

* Selections from the Records of the Government of India, No. XXV., "Andaman Islands," Preface, p. vi. I am indebted to General Sir Proby Cautley, F.R.S., for a copy of this volume. —R. O.

band, whom she serves. Brothers may have connexion with their sisters until the latter are married. Sexual connexion may take place before the men, women, and children of the party. "If any married or single man goes to an unmarried woman, and she declines to have intercourse with him, by sitting up or going to another part of the circle, he considers himself insulted, and, unless restrained, would kill or wound her. I have seen a young woman severely wounded in the thigh in such a case. All the women ran away into the jungle, and the men who restrained the violent man from further wounding her seemed to regard the matter lightly, as they laughed while they held him back*."

The bridegroom and bride smear their bodies in stripes with red earth moistened with turtle-oil, and squat on leaves spread over the ground ten or twelve paces apart. They sit in silence for about an hour. The man who marries them takes the bridegroom by the hand and leads him to where the bride is, and having seated him, without saying a word, presents him with five or six iron-headed arrows, and leaves them sitting in silence by each other until it is dark.

A pregnant woman performs her duties almost to the time labour commences. The party halts an extra day when she is confined. Several female friends collect around the woman in labour to assist her by punkahing away the flies and mosquitos. When the child is about to be born, she stands up, supported by the females, spreads out her legs, and the child is taken into the hands of one of the women ready to receive it. The umbilical cord is cut, about a finger's breadth from the body, but no ligature is applied. The afterbirth is allowed to be voided without assistance. Some hours after, the mother is anointed with the usual unguent of red earth and turtle-oil: she eats and drinks as usual. Convalescence is very rapid; and if the party has to move on the morrow, the recently-delivered woman accompanies them on foot. The child is washed in cold fresh water, poured upon it either from a bamboo water-vessel or a shell. Its wet body is dried by the hand, which is heated before the fire, and quickly and repeatedly but very gently applied. Any woman of the party who is suckling gives the new-born child her breast for a day or two until its mother's milk comes: children are suckled as long as their mothers have milk to give them. If it rains during a march, a few leaves are sewn together with rattan, and used as a covering for the infant. The parents are fond of the children, and reciprocally.

The men go into the jungle to hunt for pigs; the women stay in the encampment, supply the drinking-water, firewood, catch fish and shell-fish, cook the food ready for the men's return, make small fishing-nets, baskets, and spin twine. They catch the fish left by the ebb-tide by means of a small hand-net stretched over a hoop, and collect shell-fish from the rocks. They tattoo by incising the skin with small pieces of glass, without inserting colouring-matter, the cicatrix being whiter than the sound skin. The women make a sling, six inches wide, to suspend the infant or young child, which sits in the loose turn, with the legs passing over the mother's loins or hips.

Boys about the age of three years play with little bows and arrows, and when about eight years they are capable of taking a good aim and accompany their fathers into the jungle. The girls are very fond of playing with the sand on the beach, raising it into a circle or square around them, calling the interior their house (boov), and imitating the manners of their mothers.

In their encampments, which enclose an open central place, there is

* Report and evidence of the Brahmin sepoy.

usually one hut, square in form, built and roofed in with much more care and attention than the others, and generally richer in pigs' and turtles' heads; it is the residence of the local chief, who issues the orders as to the fight and retreat when necessary.

On a death occurring, the corpse is removed from the interior of the hut to a distance of a pace or two, where it remains until burial, which takes place a few hours after. The thighs are drawn up to the belly, the legs flexed upon the thighs; the arms placed straight upon the chest and belly, so that the hands project between the thighs; and thus, enveloped in leaves, the body is tied up like a bundle by cordage of strong creepers, the ends being knotted together to form a sling, which the carrier, with his back turned towards the corpse, puts over his head and shoulders, and with the assistance of two men rises with his burden, and is accompanied by two or three men, relatives of the deceased, to the burial-place. This is usually about a mile inland from the sea-shore. The grave is an irregularly round hole about three feet deep, dug with a pointed piece of stick, the earth being thrown out by the hands. The body is lifted into the grave by means of the sling, the earth filled in and forming a small mound.

Before the corpse is prepared for burial, the wife and one or two near relatives sit down and weep over it. Two or three months after burial, when the flesh has decomposed and been eaten by land-crabs and ants, some near relatives of the deceased proceed to the spot and disinter the bones; and having bound them together with creeper-cords, carry them to the encampment and spread them out, when these are wept over by the relatives, each of whom takes a bone, the nearest relative taking the skull and lower jaw, which may be carried suspended by a cord from the neck for months. The bones are sometimes bound to the posts of the hut.

The chief weapons of the Andaman race are bows and arrows, the latter with iron heads. A chief has been observed to have a spear, his bow and arrows being carried by a henchman.

The hair is shaved, the skin scarified in certain maladies, and the tattooing performed by pieces of glass—chips of bottle-glass skilfully detached by sharp blows of a stone.

The materials for the above weapons, viz. iron and glass, are obtained from wrecks. If flint-nodules were present in the Andamans, no doubt the native instinct, and notices of the appearances of accidental fractures of such nodules, would have led to the formation of the primitive knife from flint, as from glass.

The Andamaners appear to be devoid of fear; they are powerful for their size; can carry greater burdens than the Hindoos; are swift runners, and clear rapidly, by jumping, the fallen trees of the jungle and rocks of the tidal shore. As climbers they are little inferior to monkeys, being used from childhood to climb the lofty, straight, unbranched trees of the forest in quest of fruit and honey. They are excellent swimmers from their childhood, and wonderful divers, "fishing for shell-fish in deep water." "I have seen," deposes the sepoy, "three or four of them dive into deep water and bring up in their arms a fish, six or seven feet in length, which they had seized." .... "They could perceive canoes approaching long before they were visible to me, and could see fruits and honeycombs in the jungle which I could not. Their vision penetrates to great depths in the sea, where they could see and shoot fish with arrows, when the object aimed at was not apparent to me. They see well at night, catching fish in the pools left by the tide at that season, and shooting the wild pigs which come to the coast to drink by night." By their acute sense of smell they often detect afar off the existence of fruit in the neighbouring lofty trees.

In regard to their maladies, the sepoy deposes :—"I never met with any one affected with gonorrhœa, syphilis, itch, piles, small-pox, or goître; but I have seen them affected with vomiting, colic, diarrhœa, intermittent fever, headache, ear-ache, toothache, abscesses, rheumatism, catarrh, cough, painful and difficult respiration. The only remedies I have seen used are 'red earth rubbed up with turtle-oil,' a cold infusion of certain aromatic leaves, the wetted leaves being applied to the head or other inflamed parts, and local bleedings by sharp splinters of bottle glass."

They spin ropes, make wicker baskets, large nets for catching turtle, smaller nets for catching fishes; and they scoop out their canoes by means of a small kind of adze, tipped by a semicircular blade of iron. Thus, for all their immediate wants, invention has supplied the instruments called for by the nature of the surrounding objects and sources of food. "It is impossible," writes Dr. Mouatt, Inspector-General of Jails, Calcutta, "to imagine any human beings to be lower in the scale of civilization than are the Andaman savages. Entirely destitute of clothing, utterly ignorant of agriculture, living in the most primitive and rudest form of habitations, their only care seems to be the supply of their daily food." Thus the low grade of humanity, hardly raised above that of the brute animal, with the dwarfish stature and dark sooty colour of the Andamaners, have always made a further knowledge of their physical characters peculiarly desirable.

I am enabled to contribute the present notice of the osteological and dental characters of the Mincopie race, by the opportunity kindly afforded me by Dr. Fred. J. Mouatt, Inspector of Indian Jails, who brought over the bones of an adult male native of the Andamans, which he has since presented to the British Museum. The proportions of the bones indicate a well-formed, robust, adult male of four feet ten inches in height. The bones present a compact sound texture, with the processes, articular surfaces, and places of muscular attachments neatly defined. The cranium (Plates VI. and VII.) is well formed, not exceeding disproportionately in any diameter; it might be classed with those of the oval type (Plate VII. figs. 1 and 2). The frontal region is rather narrow, but not very low for the size of the cranium; it recedes or passes by a regular curve from the glabella (Plate VI. *g*) upward and backward to the vertex, *v*. The frontal, much of the sagittal, and the upper part of the coronal sutures are obliterated. Part of the lambdoidal suture is very complex, and sinks below the level of the contiguous bones at the lower angle and 'additamentum,' *l*. The alisphenoid ($_6$) joins the parietal ($_7$) on both sides of the head. The glabella is but little prominent; the nasals ($_{15}$) are not flat, but are moderately developed. The alveolar parts of the upper and lower jaws slightly project. The chin is a little produced, is not deep. The malar bones ($_{26}$) are not unusually prominent: in this respect, as well as in the minor breadth of the cranium, the skull departs from the type of the Malay. The zygomatic process of the squamosal ($_{27}$) is slender. The styliform process of the alisphenoid overlaps the inner angle of the vaginal process. The cranial bones are not above the average thickness.

The following are the principal dimensions of this cranium :—

	in.	lin.
Length, from inion *i* to premaxillary border ($_{22}$) (178·0)	7	0
Do. from do. to glabella (160·0)	6	4
Breadth of the cranium (144·0)	5	4
Circumference of the cranium (409·0)	19	6
Ante-posterior diameter of the interior of the cranium (150·0) ..	5	9
Transverse diameter of ditto (145·0)	5	7
Vertical diameter of ditto (115·0)	4	6

The spine of the occiput is not so developed as to interrupt the convex contour of the occipital part of the skull; the lower occipital crest is rather more developed than the upper one. The mastoids (8) are moderately developed; there is no supermastoid ridge, nor any process from the paroccipital (4). The base of the skull offers all the strictly human characteristics. There is no excess in the size of the orbits or of the auditory apertures; a sharp ridge projects from the lower boundary of the anterior nares. The lower jaw shows a variety in the shape of the coronoid process (30) which is occasionally seen in Europeans; it is broader and lower than usual; the front border is more convex at its upper half, and forms with the concave lower part a deeper and more decided sigmoid curve. The ascending ramus forms a less open angle with the horizontal ramus than in most Negro and Australian skulls.

The teeth (Plate VII. fig. 3) equal in size the average of those of Indo-Europeans; they correspond in this respect with those of the European figured in my 'Odontography,' plates 118 and 119. Although they are large in proportion to the size of the jaws, they are markedly smaller than are those of the Australian figured in the same plates. In the upper jaw of the male Andamaner the true molars, as in most Europeans, diminish in size from the first (*m* 1) to the third (*m* 3). The fissure which penetrates the grinding surface from the outer side to the middle of the crown had its end unobliterated in *m* 1, and retained its whole length in *m* 2. The enamel was worn from the inner half in both teeth, but in a less proportion in *m* 2; it was also slightly worn from the outer tubercles in *m* 1. The degree of abrasion of the teeth, according to the age of the individual, is such as might be expected from the mastication of a diet consisting chiefly of fish and fruit. In the lower jaw the dentine is exposed on the three outer tubercles of *m* 1; the crucial figure is not obliterated in *m* 2; *m* 3 is larger, as usual, than in the corresponding tooth above. The upper premolars are implanted by a fang which is divided at its base into an outer and inner root. The undivided fang of the lower premolars is longitudinally grooved on the outer side. In the upper jaw, *m* 1 and *m* 2 are implanted by one inner and two outer roots, *m* 3 by one antero-external root and one postero-internal root. All the lower molars have distinct anterior and posterior roots. There was no irregularity in the position, nor any sign of decay in the teeth.

The articulations of the skull with the vertebral column in the present skeleton of the Andamaner agree with those of the male sex in the highest variety of the human species. One of the most characteristic differences between man and all other mammals consists in the fact that the human head is balanced in the erect posture, only requiring slight muscular action to steady it, while the skull of the chimpanzee and all lower mammals preponderates anteriorly, and needs to be sustained by the action of powerful muscles and elastic structures. To preserve the equilibrium of the human head, the cerebrum in its growth extends more backward than forward, developes the posterior lobes with their contained structures peculiar to man, and produces a concomitant expansion and production of the occipital part of the cranium during the progress of general growth from infancy to adult age, whereby the back of the head becomes balanced against the increasing weight of the face.

All the bones of the trunk and limbs of the male Mincopie present the specific and generic characters of *Homo sapiens*, Linn. The sigmoid flexure of the clavicle (52) is well marked. The scapula (51) agrees with that variety of form which shows a minor extent of the supraspinal tract, and a greater breadth of the lower part of the subspinal tract, with a more produced angle between the surfaces for the teres major and teres minor muscles, on the inferior costa.

The inferior costa describes a continuous concave curve from the angle to the base of the coracoid, without any suprascapular notch. The os innominatum, calcaneum, astragalus, and bones of the hallux or great toe, peculiar to man, contrasted as strongly with the quadrumanous characters of those bones as in the highest of the human races. The first lumbar vertebra had the diapophysis, metapophysis, and anapophysis distinct, and almost equally developed, and well illustrated the true serial homology of the longer diapophysis of the succeeding lumbars. In many European skeletons the diapophyses of the first lumbar vertebra are more developed than in that of the Andamaner. The ridges, processes, and surfaces for muscular attachment are well and neatly defined on the several limb-bones of this skeleton, and agree with the character for agility in running, climbing, and swimming assigned to the Andaman race.

The following are the dimensions of the limb-bones:—

	in.	lin.
Scapula.		
Length from end of acromion to inferior angle	7	1
Breadth from upper and outer angle to lower border of glenoid cavity	4	0
Os Innominatum.		
Length	7	7
Breadth of ilium	5	5

	Humerus.		Ulna.		Radius.		Femur.		Tibia.		Clavicle.	
	in.	lin.	in.	lin.	in.	lin.	in.	lin.	in.	lin.	in.	lin.
Length	12	2	10	8	9	11	17	5	14	3	5	2
Transverse diameter of upper end	1	10	1	2	0	10	3	4				
Do. of middle	0	9	0	6	0	$6\frac{1}{2}$	0	11	1	1		
Do. of lower end	2	$1\frac{1}{2}$	0	9	1	3	2	9	1	10		

The above dimensions of parts of the skeleton indicate that they are from an individual of four feet ten inches in height.

The Andamaners, or Mincopies, are called by most of the observers who have described them "Negrillos," or dwarf Negroes. They have no knowledge, and appear to have no idea, of their own origin. It has been surmised that they might be descendants of African Negroes, imported by the Portuguese for slave labour in their settlement at Pegu, and which had been wrecked on the Andamans. But the recorders of this hypothesis allude to it as a mere hearsay—"We are told that when the Portuguese," &c. (Calcutta Monthly Register, or India Repository, November 1790, pp. 15–17). Neither the skull nor the teeth of the male Andamaner above described offer any of the characters held to be distinctive of the African Negroes. The cranium has not the relative narrowness ascribed to that of the Negro; it presents nothing suggestive of lateral compression; it conforms to the full oval type, with a slight degree of prognathism, and is altogether on a smaller scale than in the Indo-European exhibiting that form of skull. It is to be presumed that the Portuguese would import from the Guinea coast, or other mart of Negro slaves, individuals of the usual stature; and it is incredible that their descendants, enjoying freedom in a tropical locality affording such a sufficiency and even abundance of food as the Andamans are testified to supply, should have degenerated in stature, in the course of two or three centuries, to the characteristic dwarfishness of the otherwise well-made, well-nourished, strong and active natives of the Andaman Islands. I conclude, therefore, that they are aborigines; and merely resemble Negroes in a blackness, or rather sootiness, of the tegumentary pigment, which might be due to constant exposure during many generations of this nude and primitive race. Their prognathism is not more than is found in most of the Southern Asiatic peoples, and indeed in the lower orders of men in all countries, and may be due or relate to the prolonged sucking of the plastic infant. The growth of the short, crisp hair of the scalp, by small tufts, shows a resemblance of the Andamaners to certain Papuans, as, *e. g.*, those of New Caledonia. But the skull and dentition of the Andaman male are as distinct from the Australian type as from that of the West-coast Negro. There is no supranasal ridge due to a sunken origin of the flattened nasal ($_{15}$) bones; neither the malar ($_{26}$) nor zygomatic arches show the strength and prominence that mark them in the Australian male; there is no excessive size of molar or other teeth. The styliform processes of the alisphenoid are more produced; the lambdoidal suture is more complex; the alisphenoids ($_{6}$) are relatively broader. From the present opportunity of studying the osteology and dentition of the Andamaner, the ethnologist derives as little indication or ground of surmise of the origin of the race in question from an Australasian as from an African continent; and there is scarcely better evidence of his Malayan or Mongolian ancestry. Upon the whole, the skull offers the greatest amount of correspondence with those of such of the dwarfish, dark, and presumed aboriginal inhabitants of the Philippines, Java, Borneo, and Ceylon, which I have had the opportunity of examining. I cite the descriptions of two of these crania from my Catalogue of the Osteological Series in the Museum of the Royal College of Surgeons. In that of an aboriginal native of Luzon (No. 5531), "the cranium is short, moderately broad, rather low, with a narrow and receding forehead. The glabella is prominent through the development of the frontal sinuses; the nasals are moderately prominent, as are likewise the malars and upper jaw. The chin is well developed. The entire skull is rather small. The chief individual peculiarity is seen in the development of the right paroccipital, which is longer than the mastoid, and presents an articular surface for joining its homotype, the diapophysis of the atlas. The left paroccipital tubercle is also well marked. The deviation from the Human type here presented, if compared with the skull of an inferior mammal, *e. g.* the Bear, or the Dog, will be perceived to be a return to a more general type, which is manifested by the more constant development, in the Mammalian series, of the paroccipitals or transverse processes of the occipital vertebra." (Vol. ii. p. 861.) In the cranium of a Veddah, or aboriginal of Ceylon (No. 5539), "the cranial cavity is of small size, with the forehead narrow and receding: the glabella is moderately prominent through the development of the frontal sinuses. The sutures are well marked; that of the lambdoid is particularly complex, and sinks below the level of the contiguous bones at its lower angles*. The supramastoid ridge is well marked; the mastoids are moderately developed: the paroccipitals are rudimentary. The zygomatic processes of the temporals are very slender; those of the malars have the lower border convex, descending below them. The styliform processes of the alisphenoid are low, or short, subquadrate, but unusually extended backwards and outwards, overlapping the inner angle of the vaginal processes. A trace of the maxillo-premaxillary suture remains on the palate: the maxilla is slightly prognathic: the molar teeth are small. This cranium has probably belonged to a female: it agrees in the chief characters with the skull from the Philippines (No. 5531)." (Ib. p. 863.)

I am not cognizant of any anatomical grounds for deriving the Andaman

* Mr. C. C. Blake has noticed this character in other Veddah skulls. See 'Medical Times,' May 17, 1862.

people from any existing continent; but, in making these remarks, I would offer no encouragement to the belief that they originated in the locality to which they are now limited.

It has been said that "their language shows them to belong to the same division with the Burmese of the opposite continent." But late vocabularies oppose this view. The Burmese, moreover, show the average stature of the southern Asiatic men; and it would be as pure an assumption to affirm that they had been derived from the Andamaners, as that these were degenerate descendants of the Burmese.

The few undersized, dark-skinned aborigines, as they are termed, of the Great Nicobar, of the Philippines, of Java, Borneo, Sumatra, and Ceylon, are driven furthest into the interior by immigrants of other races, and are the least likely to have emigrated or equipped vessels for the purpose of voyaging to other lands. The average-sized Malay and Chinese, and the like later colonists of the Indian Archipelago, are those that have the command of the sea; and the Andamaners are certainly not their descendants.

Combined geological, geographical, and zoological researches have made us cognizant of the fact of the formation and destruction of continental tracts of land in the known course of the earth's period of existence. The Andaman Islands, like the Nicobar, Java, Sumatra, and Ceylon, may have been parts of some former tract of dry land, distinct from, and perhaps pre-existent to, that neighbouring and more northern continent which has been the scene of the elevation of the Himalayan range of mountains, in part—perhaps a great part—within the tertiary period. This has been the opinion of geologists for some time back, and is alluded to by Professor Ansted in his 'Ancient World,' pp. 322, 324. The extensive collections and assiduous comparisons of the animals of Ceylon by Sir J. Emerson Tennent have added valuable evidence in favour of such opinion*. The Andamans are forty miles distant from the nearest islands, the Cocos, on their north, and seventy-two miles distant from the Nicobar Islands on their south. There is a mountain 2400 feet in height called "Saddle Peak," probably volcanic, on the main island; and there is a volcanic island in the vicinity called "Barren Island," with an active volcano. The whole of the shores of the Andamans are skirted by continuous coral-reefs. It is plain that the Andamans are the active seat of those causes that influence the change in the relations of land to sea. We should doubtless err, therefore, in any speculation on the origin of their population, if we were to assume that the Andaman Islands were such as they now are when they received their first human inhabitants.

The cardinal defect of speculators on the origin of the human species seems to me to be the assumption that the present geographical condition of the earth's surface preceded or coexisted with the origin of such species. The monogenist, on that assumption, bent on tracing all human races from one source and one existent centre, exaggerates the application and value of casual remarks to show, for example, that "the Australians are not a pure race, but hybrids between true Negroes and a Malayan or yellow race." (See Quatrefages' 'Unité de l'Espèce Humaine,' 12mo, 1861, p. 173.) And the polygenist invokes a separate creation of each race for each existing continent or island-home of such race. (Agassiz, in Nott and Gliddon's 'Types of Mankind.')

The Andamaners are perhaps the most primitive, or lowest in the scale of civilization, of the human race. They have no tradition, and, as has been before remarked, apparently no notion of their own origin. Finding in their bows and arrows and their hand-nets implements that answer for acquiring the principal articles of food which their locality yields, they have carried

* Natural History of Ceylon, 8vo, 1861.

Plate VI.

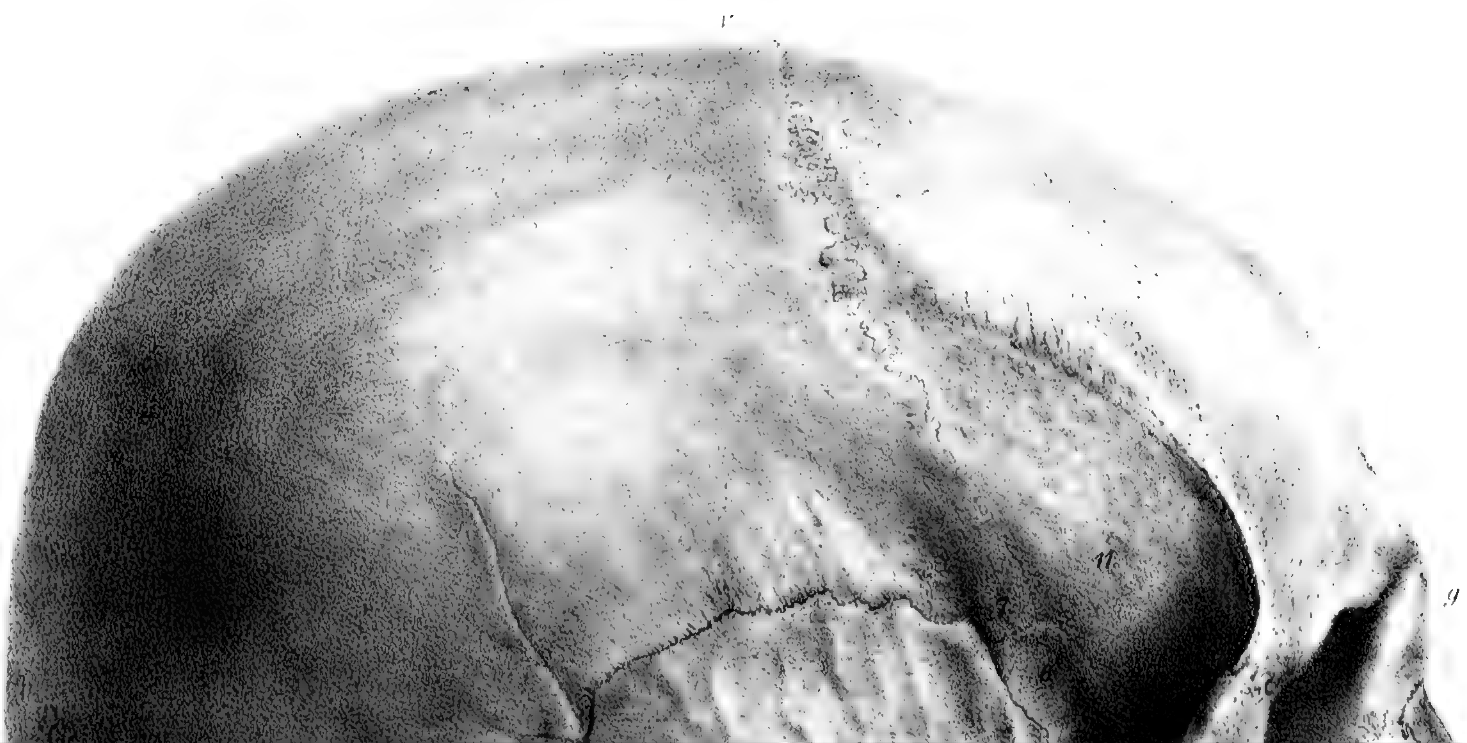


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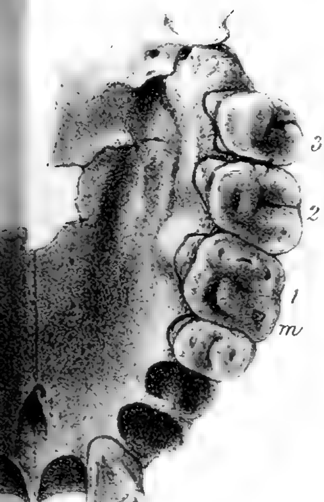
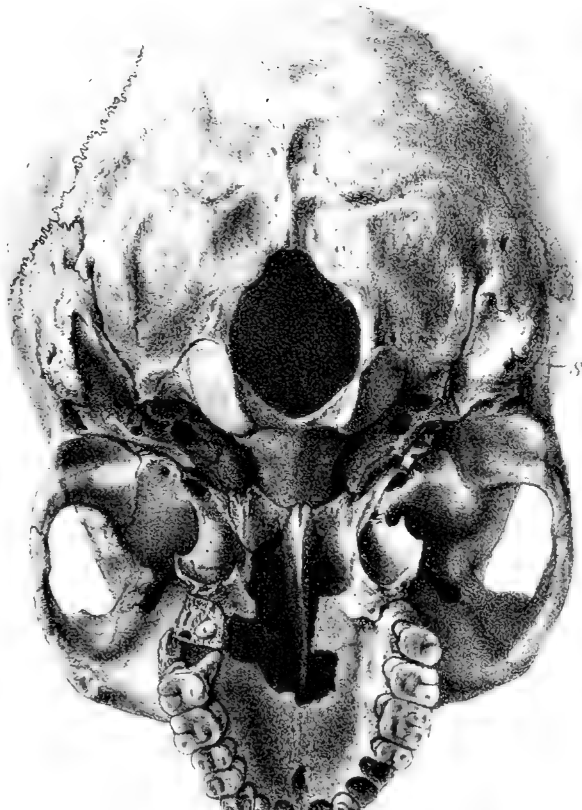
Plate VII

Fig. 3.





W West imp

DAMAN

the inventive faculties no further. At best they may have availed themselves of the wrecks during the last century or two of their insular existence, to barb their arrows with iron instead of fish-bone, and to get from broken bottles such trenchant fragments as our oldest-known Europeans obtained from broken flints. The animal appetites are gratified in the simplest animal fashion; there is no sense of nakedness, no sentiment of shame. The man, choosing promiscuously for one or more years after puberty, then takes, or has assigned to him, a female who becomes his exclusive mate and servant; and the reason assigned for this monogamy is that she may be restricted, while he may continue to select from the unmarried females as before. The climate dispenses with the necessity of any other protection of the body than a paste of earth and oil. Any rudiment of a cincture relates solely to the convenience of the suspension of weapons or other portable objects. They are not cannibals. Implacably hostile to strangers, the Andamaners have made no advance in the few centuries during which their seas have been traversed by ships of higher races. Perhaps the sole change is that of the materials for weapons derived from casual wrecks, to which allusion has already been made.

Enjoying, therefore, the merest animal life during those centuries, why may they not have so existed for thousands of years? The conditions of existence being such as they now enjoy, on what can the ethnologist found an idea of the limitation of the period during which the successive generations of Andamaners have continued so to exist? Antecedent generations of the race may have coexisted with the slow and gradual geological changes which have obliterated the place or continent of their primitive origin, whatever be the hypothesis adopted regarding it.

In every essential of human physical character, however, the present Mincopies or Andamaners participate with their more intellectually gifted brethren. The size of the brain, indicated by the cranial chamber, promises aptitude for civilization. The Andamaners resemble the orangs and chimpanzeee only in their diminutive stature; but this is associated with the well-balanced human proportions of trunk to limbs: they are, indeed, surpassed by the great orangs and gorillas in the size of the trunk and in the length and strength of the arms, in a greater degree than are the more advanced and taller races of mankind.

PLATE VI.

Side view of the skull of the male native of the Andamans: natural size.

PLATE VII.

Fig. 1. Front view } of the same skull, on the scale of ½ an inch to an inch.
Fig. 2. Base view }
Fig. 3. Bony palate and grinding surface of the teeth of the same skull: natural size.

Report from the Balloon Committee. By Colonel Sykes, *M.P., F.R.S.*

Professor Walker, after the appointment of the Committee at the Aberdeen Meeting, having communicated to Colonel Sykes his inability to undertake any *active* labours with respect to carrying out the objects for which the Committee was nominated, Colonel Sykes put himself into correspondence with Mr. Langley, a gentleman of Newcastle, who offered to construct a suitable balloon, provided an advance of money were made to him. The correspondence however was without result, and Colonel Sykes in consequence thought it unnecessary to invite the opinions of the other members of the Committee with respect to the objects to be sought for in balloon-ascents, as means were wanting, whatever those opinions might be, to give practical effect to them. Colonel Sykes was not at the meeting at Oxford last year, and no action having been taken by the Balloon Committee, it has dropped through and is extinct.

Within a few months past Mr. Simpson, of Cremorne Gardens, has constructed a balloon at a cost of £600 (the 'Normandie'), with a sufficient capacity to carry two persons to great heights, which might be available for the objects of the Association. The occasion has therefore arisen when the re-appointment of a Balloon Committee might take place; and as one of the chief objects of the last Balloon Committee, viz. the verification of the former results of the ascents undertaken by the authority of the Association, remains unchanged, Colonel Sykes, with the approval of those members of the late Balloon Committee with whom he has had an opportunity of conversing, will move the re-appointment of the Committee with a grant of £200.

Report on the Repetition of the Magnetic Survey of England, made at the request of the General Committee of the British Association. By Major-General EDWARD SABINE, *R.A., President of the Royal Society.*

THE Magnetic Survey of the British Islands, corresponding to the epoch of January 1, 1837, which had been undertaken in 1836 at the request of the British Association, was completed in 1838, and a coordinated Report of the observations of the Dip and Force, contributed by each of the five Members of the Association who had cooperated in the execution of the Survey, was published in the annual volume for 1838, accompanied by Maps of the Isoclinal and Isodynamic Lines embodying the results of the Survey. The observations of the third element, the Declination, which were made chiefly by one of the cooperators, Sir James Clark Ross, were not published until a later date, when, having been reduced and coordinated by myself, they were included in a memoir printed in the Philosophical Transactions for 1849, entitled "On the Isogonic Lines, or Lines of equal Magnetic Declination in the Atlantic Ocean in 1840," in which they completed in a very satisfactory manner the N.E. portion of the map accompanying that memoir.

The Magnetic Survey of 1837 deserves to be remembered as having been the first complete work of its kind planned and executed in any country as a national work, coextensive with the limits of the state or country, and embracing the three magnetic elements. The example thus presented was speedily followed by the execution of similar undertakings in several parts of the globe; more particularly in the Austrian and Bavarian dominions, and in detached portions of the British Colonial Possessions, viz. in North America and India. The immediate object of such surveys is to determine for the particular epoch at which they are made, the positions of Lines of equal Declination, Inclination, and Magnetic Force in the area of the Survey; the angles at which the three classes of lines respectively cross the geographical meridians; and the distances in geographical miles, measured in directions perpendicular to the lines, which correspond to equal increments of each of the magnetic elements. By the extension and multiplication of such surveys far more satisfactory materials are supplied for the construction of general magnetic maps of the globe than are afforded by the desultory observations which had previously formed their only basis. This, as already stated, is the *immediate* object of such Surveys; but they have in prospect another and a scarcely less important purpose, in contributing by their repetition at stated intervals to supply the best kind of data for the gradual elucidation of the laws and source of the *secular change* in the distribution of the earth's magnetism, perhaps the most remarkable of the yet unexplained natural phenomena of the globe.

It was in this view that the General Committee of the British Association, assembled at Cheltenham in 1856, considering that in 1857 twenty years would have elapsed since the epoch of the first Survey, passed the following Resolution,—"That a Committee, consisting of General Sabine, Professor Phillips, Sir James Clark Ross, Mr. Robert Were Fox, and the Rev. H. Lloyd, be requested to undertake the Repetition of the Magnetic Survey of the British Islands." The five members of the Association named in this Resolution were the same by whom the former Survey had been made, and were all living at the time of the Cheltenham Meeting, Dr. Lloyd and Mr. Phillips being present at it. I was myself on the continent for the recovery of health, but on my return in the autumn of 1856, finding my own name standing first in the list of the Committee, I lost no time in making such arrangements as seemed suitable for the accomplishment of the purpose which the Association had in view. Dr. Lloyd undertook the Irish portion; Scotland and the islands to its North and West were placed, with the consent of the Committee of the Kew Observatory, in the able hands of Mr. Welsh, the Superintendent of that establishment, and a grant of £200 was obtained from the Admiralty towards the payment of his travelling expenses. For some time I cherished the hope that the repetition of the English Survey might be accomplished (as on the previous occasion) by the joint labours of the Members of the Committee: but at length it became evident that circumstances of health or the pressure of other employments and duties stood in the way of a combined operation; which would have necessitated also a great amount of additional labour in the intercomparison of the different instruments and methods employed. I have made therefore the whole of the observations for the isoclinal and isodynamic lines myself; but having only a portion of each year at my disposal, they have required the summers of 1858, 1859, 1860, and 1861, causing January 1, 1860, to become the middle epoch of the Survey, in respect to these two of the three elements. The detail of the observations, the conclusions derived from them, and the maps of the two elements, constitute the two first divisions of the present Report; the third division, containing the observations upon which the map of the isogonic lines for 1857 is based, together with the comparison of these lines with those of the earlier Survey, and the deduction of the mean secular change of this element in the interval, has been contributed by Frederick John Evans, Esq., F.R.S., Superintendent of the Compass Observatory of the Royal Navy at Woolwich.

The premature decease of Mr. Welsh, accelerated it is feared by his too persistent exposure in the second year of the Scottish Survey, left the reduction and publication of the northern portion of the British Survey to his successor at Kew, Mr. Balfour Stewart, by whom a report has been presented to the General Committee, which report is printed in the annual volume for 1859. There remains, therefore, now, for the entire fulfilment of the desire embodied in the Resolution of the General Committee at Cheltenham in 1856, only the Irish portion of the Survey, which has been undertaken by Dr. Lloyd, to whom have been added as coadjutors, by his own request, the Rev. Professors Galbraith and Haughton, and George Johnstone Stoney, Esq. Dr. Lloyd has acquainted me that it is his wish, and that of the gentlemen associated with him, that the Irish portion of the Survey should be published in the 'Transactions of the Royal Irish Academy.' The present is therefore the concluding Report addressed to the British Association of the Committee nominated by them at the Cheltenham Meeting in 1856.

Division I.—*Dip.*

In selecting an instrument to be employed, in a magnetic survey, for the purpose of determining the position, direction, and distance apart of the isoclinal lines, care must be taken, 1st, that its "probable error" be small, so that the observations made at the different stations of the survey may be as far as possible comparable with each other; and 2nd, that what is usually termed the "Index Error" be either so small as to be practically insignificant, or that, if of significant amount, its value should be carefully determined by a sufficient examination at a base station, so that the general conclusions of the survey may be comparable with those of similar surveys made in other countries at the same epoch. The instrument selected for this survey was one of the well-known English pattern which has been adopted for some years past at the Kew Observatory; the circle was 6 inches in diameter, fitted with both verniers and microscopes, and with two needles, each $3\frac{1}{2}$ inches in length. An examination of the results obtained with twelve circles of this pattern with their 24 needles in 282 determinations made by different observers at the Kew Observatory, has been published in the 11th volume of the 'Proceedings of the Royal Society,' pp. 145–162. The circle there distinguished as No. 30 was the one selected for the English survey, and was employed at all the stations of observation in 1858, 1859, and 1860. In the autumn of 1860, the English survey being then supposed to have been completed, No. 30 was sent to the Magnetic Observatory at the Isle Jesus, near Montreal in Canada, on the application of Dr. Smallwood, Director of that observatory; but the pressure of other avocations having obliged me to defer for a few months the preparation for the press of the results obtained in 1858, 1859, and 1860, I was enabled in the summer of 1861 to add four more stations on the eastern coast of England, and for these observations I obtained from the Kew Observatory the use of the Circle No. 33, which (with its two needles) had been one of the twelve employed in the comparison at Kew, of which the account is published in the 'Proceedings of the Royal Society' as above stated. Referring to that account, it will be seen that 28 of the 282 determinations at Kew with the twelve circles were made with No. 30, and 49 with No. 33; and after the proper corrections for secular change and annual variation, we find the "probable error" of a single determination to be with No. 30 $\pm 1'{\cdot}25$, and with No. 33 $\pm 1'{\cdot}18$; whilst the "probable error" derived from the 282 determinations obtained with the twelve circles is $\pm 1'{\cdot}45$. We may therefore regard Nos. 30 and 33 as instruments superior rather than inferior, in the intercomparability of the results obtained with them, to the average of their class; which class is, I believe, unsurpassed by any other form of instruments in use either in our own or in any other country for the determination of the magnetic dip.

In regard to the question whether any and what "index correction" should be applied to the results obtained with Nos. 30 and 33, it may be seen by an examination of the results in the 'Proceedings of the Royal Society' already referred to, that the mean result of the 28 determinations at Kew with No. 30 exceeded the mean of the 282 determinations with the twelve circles by $+0'{\cdot}8$, and the mean of the 49 determinations with No. 33 exceeded the mean of the 282 by $+0'{\cdot}7$. These differences have appeared too small to require the assignment of a specific index correction to Nos. 30 or 33; it is sufficient to record the circumstance, and to remark that it is possible that the values of the isoclinal lines at the epoch of January 1st, 1860, given in the present memoir, which rest on the results obtained with these circles, may be a fraction of a minute, or even a whole minute too high.

I proceed in the following Table to state the observations of the Dip made with Nos. 30 and 33 at the several stations of this survey: the observations were made by myself, unless where otherwise noted.

TABLE I.—Observations of the Magnetic Dip with Circle 30 at Kew.

Date.	Needle.	Azimuths.	Mean Dip. Poles reversed and Needle inverted.	Observer.	Place of Observation.
		° °	° '		
1858. March 30.	1	30 and 120	68 28·3	Mr. Welsh.	In the Magnetic House of the Observatory.
" 30.	1	60 " 150	68 23·0		
" 30.	1	0 " 180	68 23·2		
" 30.	1	60 " 150	68 25·2		
" 30.	2	0 " 180	68 25·1	Mr. Chambers.	
" 30.	2	30 " 120	68 26·9		
" 30.	2	60 " 150	68 27·0		
" June 9.	1	0 " 180	68 21·1	Mr. Welsh.	
" 9.	2	0 " 180	68 21·6		
1859. " Jan. 11.	1	0 " 180	68 23·7	Mr. Chambers.	
" 11.	1	0 " 180	68 24·6		
" 12.	2	0 " 180	68 23·7		
" 12.	2	0 " 180	68 24·4		
" 24.	1	0 " 180	68 22·7		
" 24.	1	0 " 180	68 21·6		
" 25.	2	0 " 180	68 24·1		
" 25.	1	0 " 180	68 22·2		
" Mar. 8.	1	0 " 180	68 21·7		
" 8.	2	0 " 180	68 22·2		
" 17.	1	0 " 180	68 21·7		
" 17.	2	0 " 180	68 24·4		
(1) 1858. Sept.	Mean at the Station...		68 23·7		

TABLE I. (continued).

Station and Date.	Needle.	Marked End. N. Pole.	Marked End. S. Pole.	Means.		Place of Observation.
St. Leonards.		° '	° '	° '	° '	
(2) 1858. June 23.	1 Direct ...	67 40·2	67 59·2	67 49·7	67 48·5	In the grounds of Dr. Blakiston at Hollybank.
" 23.	2 Direct ...	67 47·8	67 43·4	67 45·6		
" 26.	1 Direct ...	67 41·6	67 58·0	67 49·8		
" 26.	2 Direct ...	67 50·7	67 46·1	67 48·4		
" July 1.	1 Direct ...	67 41·0	67 59·6	67 50·3		
" 1.	2 Direct ...	67 49·0	67 45·4	67 47·2		
Llandovery.						
(3) 1858. July 21.	1 Direct ...	69 05·3	69 23·5	69 14·4	69 13·0	In the grounds of W. Leeves, Esq., St. Mary's Cottage.
" 21.	2 Direct ...	69 15·7	69 12·7	69 14·2		
" 22.	1 Direct ...	69 03·7	69 21·7	69 12·7		
" 22.	2 Direct ...	69 14·2	69 11·6	69 12·9		
" Sept. 7.	1 Direct ...	69 02·7	69 21·3	69 12·0		
" 7.	2 Direct ...	69 12·8	69 11·4	69 12·1		
Stonyhurst.						
(4) 1858. Sept. 30.	1 Direct ...	69 53·3	70 07·1	70 00·2*	70 00·2†	In the gardens of the College.

* Observed by the Rev. W. Kay.

† Since the observations were made at Stonyhurst, I have received a memorandum from the Rev. Alfred Weld, of the results of observations made subsequently by himself and the Rev. W. Kay, in the Gardens of the College, with the Dip Circle and its needles obtained (through the Kew Observatory) for Stonyhurst College. They are as follows:— [*Over.*

Table I. (continued).

Station and Date.	Needle.	Marked End. N. Pole.	Marked End. S. Pole.	Means.		Place of Observation.
		° ′	° ′	° ′		
Glangwnna.						
(5) 1858. Oct. 5.	1 Direct ...	69 52·5	70 11·7	70 02·1	70 02·0	In the grounds of Mrs. Hunt.
„ 5.	2 Direct ...	70 02·8	70 00·6	70 01·7		
„ 8.	1 Direct ...	69 50·6	70 10·8	70 00·7		
„ 8.	2 Direct ...	70 05·2	70 02·0	*70 03·6		
Teignmouth.						
(6) 1859. June 13.	2 Direct ...	68 09·2	68 06·8	68 08·0	68 04·7	On the lawn of Trafalgar Cottage.
„ 13.	2 Inverted.	67 55·1	68 07·1	68 01·1		
„ 14.	1 Direct ...	67 59·4	68 13·2	68 06·3		
„ 14.	1 Inverted.	67 50·5	68 16·6	68 03·6		
Torquay.						
(7) 1859. June 23.	1 Direct ...	67 53·3	68 15·3	68 04·3	68 03·7	In the garden of the Apsley House Hotel.
„ 23.	1 Inverted.	67 47·5	68 13·1	68 00·3		
„ 24.	2 Direct ...	68 11·7	67 59·7	68 05·7		
„ 24.	2 Inverted.	68 09·1	67 59·9	68 04·5		
Mt. Edgecombe.						
(8) 1859. June 25.	1 Direct ...	67 59·8	68 19·8	68 09·8	68 07·9	In the grounds of the Earl of Mt. Edgecombe.
„ 25.	1 Inverted.	67 50·5	68 17·5	68 04·0		
„ 25.	2 Direct ...	68 20·9	67 59·9	68 10·4		
„ 25.	2 Inverted.	68 13·0	68 02·2	68 07·6		
Penjerrick.						
(9) 1859. June 28.	1 Direct ...	67 59·4	68 19·0	68 09·2	68 08·2	In the grounds of Robert Were Fox, Esq.
„ 28.	1 Inverted.	67 52·2	68 17·8	68 05·0		
„ 28.	2 Direct ...	68 17·0	68 03·4	68 10·2		
„ 28.	2 Inverted.	68 12·2	68 02·6	68 07·4		
„ July 4.	1 Direct ...	67 58·9	68 18·5	68 08·7		
„ 4.	1 Inverted.	67 51·6	68 17·2	68 04·4		
„ 4.	2 Direct ...	68 14·1	68 02·1	68 08·1		
„ 4.	2 Inverted.	68 21·0	68 03·8	68 12·4		
Lew Trenchard.						
(10) 1859. July 9.	1 Direct ...	68 09·6	68 27·5	68 18·5	68 17·5	In the grounds of Edward Baring Gould, Esq.
„ 9.	1 Inverted.	68 07·4	68 22·8	68 15·1		
„ 9.	2 Direct ...	68 20·4	68 15·6	68 18·0		
„ 9.	2 Inverted.	68 22·8	68 13·8	68 18·3		
Broome Park.						
(11) 1859. July 20.	1 Direct ...	67 51·5	68 14·4	68 03·0	68 01·2	In the grounds of Sir Benjamin Collins Brodie, Bart., P.R.S.
„ 20.	1 Inverted.	67 48·4	68 12·5	68 00·5		
„ 20.	2 Direct ...	67 59·0	67 56·4	67 57·7		
„ 20.	2 Inverted.	68 07·6	67 57·5	68 02·5		
„ 21.	1 Direct ...	67 52·5	68 16·7	68 04·6		
„ 21.	1 Inverted.	67 48·8	68 09·4	67 59·1		

Note continued.

Date.	Needle.	Dip.	Observer.	Date.	Needle.	Dip.	Observer
		° ′ ″				° ′ ″	
1858. Nov. 2.	A1.	69 57 44	Weld.	1859. May 12.	A2.	70 02 17	Weld.
„ 14.	A1.	70 03 30	Weld.	Nov. 17.	A1.	69 57 48	Weld.
„ 14.	A1.	70 04 21	Weld.	„ 24.	A1.	69 56 39	Weld.
1859. April 19.	A1.	70 01 13	Kay.	Dec. 10.	A1.	69 59 39	Weld.
May 8.	A1.	70 03 39	Weld.	„ 10.	A1.	69 57 38	Weld.

Mean of the 10 observations.............. 70° 00′ 27″

The results are in every case the mean of Poles Reversed and Needle Inverted.

* Observed by Miss Anna Hunt.

Table I. (continued).

Station and Date.	Needle.	Marked End. N. Pole.	Marked End. S. Pole.	Means.		Place of Observation.
Jordan Hill.		° ′	° ′	° ′		
(12) 1859. Sept. 10.	1 Direct ...	71 18·7	71 42·3	71 30·5	71 30·1	In the grounds of James Smith, Esq., F.R.S.
„ 10.	1 Inverted.	71 18·0	71 40·0	71 29·0		
„ 10.	2 Direct ...	71 34·3	71 29·7	71 32·0		
„ 10.	2 Inverted.	71 35·2	71 22·8	71 29·0		
Fern Tower.						
(13) 1859. Sept. 30.	2 Direct ...	71 28·8	71 26·6	71 27·7	71 23·9	In the grounds of J. Frederic Bateman, Esq., F.R.S.
„ 30.	2 Inverted.	71 29·5	71 19·9	71 24·7		
„ 30.	1 Direct ...	71 11·2	71 31·8	71 21·5		
„ 30.	1 Inverted.	71 13·6	71 32·0	71 22·8		
„ Oct. 3.	1 Direct ...	71 14·0	71 32·8	71 23·4		
„ 3.	1 Inverted.	71 17·6	71 29·4	71 23·5		
Jardine Hall.						
(14) 1859. Oct. 5.	2 Direct ...	70 51·0	70 45·0	70 48·0	70 43·9	In the grounds of Sir William Jardine, Bart., F.R.S.
„ 5.	2 Inverted.	70 50·9	70 39·7	70 45·3		
„ 5.	1 Direct ...	70 32·9	70 55·7	70 44·3		
„ 5.	1 Inverted.	70 31·4	70 52·8	70 42·1		
„ 8.	1 Direct ...	70 30·2	70 52·0	70 41·1		
„ 8.	1 Inverted.	70 29·9	70 54·8	70 42·4		
Scarborough.						
(15) 1859. Oct. 11.	1 Direct ...	69 41·0	70 10·2	69 55·6	69 58·5	In a ravine west of the Queen's Hotel.
„ 11.	1 Inverted.	69 44·5	70 03·1	69 53·8		
„ 11.	2 Direct ...	70 15·7	69 58·9	70 07·4		
„ 11.	2 Inverted.	70 05·9	69 52·3	69 59·1		
„ 12.	1 Direct ...	69 42·8	70 10·0	69 56·4		
„ 12.	1 Inverted.	69 50·9	70 06·9	69 58·9		
Cambridge.						
(16) 1860. May 15.	1 Direct ...	68 25·7	68 58·7	68 42·2	68 41·7	In the grounds of Professor Stokes, Lensfield Cottage.
„ 15.	1 Inverted.	68 29·2	68 52·4	68 40·8		
„ 15.	2 Direct ...	68 43·9	68 39·4	68 41·6		
„ 15.	2 Inverted.	68 45·2	68 39·0	68 42·1		
Llandovery.						
(17) 1860. July 30.	1 Direct ...	68 52·6	69 19·6	69 06·1	69 09·7	In the grounds of William Leeves, Esq., St. Mary's Cottage.
„ 30.	1 Inverted.	68 56·4	69 23·4	69 09·9		
„ 30.	2 Direct ...	69 15·2	69 10·2	69 12·7		
„ 30.	2 Inverted.	69 13·6	69 09·2	69 11·4		
„ 30.	*2 Direct ...	68 55·6	69 09·4	69 02·5		
„ 30.	*2 Inverted.	69 04·6	69 21·0	69 12·8		
„ Aug. 1.	*1 Direct ...	69 00·0	69 21·0	69 10·5		
„ 1.	*1 Inverted.	68 58·7	69 25·0	69 11·8		
Stackpole Court.						
(18) 1860. Aug. 21.	2 Direct ...	69 06·2	68 53·8	69 00·0	68 58·2	In the grounds of the Earl of Cawdor, F.R.S.
„ 21.	2 Inverted.	69 04·9	68 53·5	68 59·2		
„ 21.	1 Direct ...	68 38·9	69 09·1	68 54·0		
„ 21.	1 Inverted.	68 50·3	69 09·1	68 59·7		
Cawston.						
(19) 1860. Sept. 10.	1 Direct ...	68 39·4	69 06·0	68 52·7	68 53·7	In the orchard of the Rectory.
„ 10.	1 Inverted.	68 42·2	69 07·8	68 55·0		
„ 10.	2 Direct ...	69 01·3	68 48·5	68 54·9		
„ 10.	2 Inverted.	68 59·4	68 50·6	68 55·0		
„ 13.	1 Direct ...	68 39·0	69 04·0	68 51·5		
„ 13.	1 Inverted.	68 41·2	69 05·0	68 53·1		
Margate.						
(20) 1860. Oct. 5.	1 Direct ...	67 53·1	68 18·7	68 05·9	68 05·9	In the fields west of the Railroad Terminus.
„ 5.	1 Inverted.	67 52·5	68 16·7	68 04·6		
„ 5.	2 Direct ...	68 09·8	68 01·6	68 05·7		
„ 5.	2 Inverted.	68 11·5	68 03·3	98 07·4		

* Spare needles.

TABLE I. (continued).

Station and Date.	Needle.	Marked End. N. Pole.	Marked End. S. Pole.	Means.		Place of Observation.
Folkestone.						
(21) 1860. Oct. 8.	1 Direct ...	67 35·2	68 04·6	67 49·9	67 49·0	On the seabeach west of the Pavilion Hotel.
„ 8.	1 Inverted.	67 33·9	68 00·9	67 47·4		
„ 10.	2 Direct ...	67 50·1	67 45·9	67 48·0		
„ 10.	2 Inverted.	67 52·7	67 48·3	67 50·5		
Cleethorpe.						
(22) 1861. Sept. 14.	1 Direct ...	69 29·5	69 29·8	69 29·6	69 29·7	In a field north of the village.
Circle No. 33. 14.	1 Inverted.	69 29·5	69 27·9	69 28·7		
14.	2 Direct ...	69 28·4	69 28·4	69 28·4		
„ 14.	2 Inverted.	69 31·6	69 32·2	69 31·9		
Lowestoft.						
(23) 1861. Sept. 23.	1 Direct ...	68 34·0	68 42·2	68 38·1	68 38·6	On the Upper and Lower Denes.
Circle No. 33. 23.	1 Inverted.	68 35·6	68 40·2	68 37·9		
23.	2 Direct ...	68 37·2	68 39·4	68 38·3		
„ 23.	2 Inverted.	68 37·8	68 42·4	68 40·4		
Cawston.						
(24) 1861. Sept. 30.	1 Direct ...	68 44·5	68 57·5	68 51·0	68 52·1	In the orchard of the Rectory.
Circle No. 33. 30.	1 Inverted.	68 46·0	68 57·1	68 51·6		
30.	2 Direct ...	68 49·7	68 54·8	68 52·2		
„ 30.	2 Inverted.	68 51·4	68 55·6	68 53·5		
Cromer.						
(25) 1861. Oct. 2.	1 Direct ...	68 50·6	68 59·4	68 55·0	68 55·3	On the N.W. Cliff.
2.	1 Inverted.	68 49·4	68 56·2	68 52·8		
Circle No. 33. 2.	2 Direct ...	68 54·2	68 56·3	68 55·3		
2.	2 Inverted.	68 56·5	69 00·6	68 58·5		
2.	2 Direct ...	68 50·4	68 56·4	68 53·4		
2.	2 Inverted.	68 51·5	69 02·5	68 57·0		

TABLE I. (continued).

Station and Date.	Needle.	Azimuths.	Mean Dip. Poles reversed and Needle inverted.	Observer.	Place of Observation.
Kew.					
(26) 1860. Oct. 22.	1	0 and 180	68 18·0	Mr. Stewart.	In the Magnetic House of the Observatory.
„ 22.	2	0 „ 180	68 20·6		
„ 22.	2	0 „ 180	68 21·2		
„ 22.	1	0 „ 180	68 14·9		
„ 23.	1	0 „ 180	68 17·6		
„ 29.	1	0 „ 180	68 19·2		
„ 30.	2	0 „ 180	68 23·0		
Mean at the Station...			68 19·2		

Table II. recapitulates the stations of observation, with their latitudes and longitudes taken from the maps of the Society for Diffusing Useful Knowledge, and the mean dips at the respective epochs of observation given in Table I. reduced to the mean epoch of January 1st, 1860, by the proportional parts of the annual change according to the rates assigned in a subsequent page (261).

TABLE II.

Stations.	Lat. = λ.	Long. = μ	Dip = θ.	Stations.	Lat. = λ.	Long. = μ	Dip = θ.
	° ′	° ′	° ′		° ′	° ′	° ′
Kew	51 29	0 18 W.	68 20·3	Jardine Hall ...	55 10	3 24 W.	70 43·4
St. Leonards ...	50 51	0 33 E.	67 44·5	Scarborough ...	54 17	0 23 W.	69 58·0
Llandovery......	52 01	3 45 W.	69 09·3	Cambridge	52 13	0 06 E.	68 42·7
Stonyhurst......	53 51	2 28 W.	69 57·2	Llandovery......	52 01	3 45 W.	69 11·2
Glangwnna......	53 08	4 14 W.	69 58·8	Stackpole Court	51 38	4 55 W.	68 59·9
Teignmouth ...	50 33	3 30 W.	68 03·1	Cawston	52 47	1 12 E.	68 55·3
Torquay	50 28	3 32 W.	68 02·2	Margate	51 23	1 23 E.	68 07·7
Mt. Edgecombe	50 21	4 11 W.	68 06·4	Folkestone	51 05	1 10 E.	67 51·0
Penjerrick	50 08	5 07 W.	68 06·6	Cleethorpe	53 32	0 00	69 33·4
Lew Trenchard.	50 39	4 11 W.	68 16·1	Lowestoft	52 30	1 45 E.	68 42·5
Broome Park ...	51 14	0 18 W.	68 00·0	Cawston	52 47	1 12 E.	68 56·1
Jordan Hill......	55 52	4 19 W.	71 29·5	Cromer	52 56	1 17 E.	68 59·3
Fern Tower......	56 22	3 50 W.	71 23·4	Kew	51 29	0 18 W.	68 21·2

Mean epoch 1st January, 1860. Mean latitude, $52° 20' = \lambda_1$. Mean longitude $1° 41'$ W. $= \mu_1$. Mean dip at the central station $68° 59'{\cdot}2 = \theta_1$.

The stations and dips contained in the preceding Table require to be combined according to the method described in the 'British Association Report' for 1838, p. 68 (and adopted in the British Magnetic Survey for 1837), in order to determine (u) the angle which the isoclinal lines in England make with the meridian, and (r) the distance between them corresponding to differences of 1° of dip measured on the normal or perpendicular to the direction of the isoclinal lines themselves. Thus, if we make a and b coordinates of distance, in geographical miles, of the several stations in longitude and latitude from the central position, and if we put $r \cos u = x$, and $r \sin u = y$, we have from Table II. 26 equations of condition of the form

$$\theta - \theta_1 = ax + by\,;$$

combining these by the method of least squares, we find

$$x = +0{\cdot}1993\,;\ y = +0{\cdot}5911\,;\ u = -71° 22'\,;\ \text{and } r = 0'{\cdot}624.$$

The most probable dip at each station will therefore be given by the formula

$$\theta = +68° 59'{\cdot}2 + 0{\cdot}1993a + 0{\cdot}5911b,$$

a and b being the distances in longitude and latitude, expressed in geographical miles, from the central position in 1° 41′ W. longitude, and 52° 20′ N. latitude.

Table III. contains in columns 2 and 3 the values of the coordinates a and b for the stations named in column 1; in columns 4 and 5 are placed the values of $(\theta - \theta_1)$, in column 4 as observed, and in column 5 as calculated; in columns 6 and 7 the dips at each station are shown, viz. the observed dips in column 6 and the calculated dips in column 7; and in the final column the differences are stated between the observed and calculated dips. From these differences we obtain $\pm 3'{\cdot}85$ as the probable error of the observed dip at a single station in this survey. This small amount of probable error will doubtless contrast favourably with the results in countries where igneous rocks are of more frequent occurrence than they are in England; it includes both station anomalies and the effects of magnetic disturbances, as well as observational and instrumental errors.

Table III.

Stations.	$(\mu-\mu_1)\cos\lambda$.	$(\lambda-\lambda_1)$.	$\theta-\theta_1$.		θ.		Observed minus Calculated.
	a.	*b*.	Observed.	Calculated.	Observed.	Calculated.	
(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)	(8.)
	Miles.	Miles.	′	′	° ′	° ′	′
Kew	− 52	− 51	− 38·9	− 40·5	68 20·3	68 18·7	+01·6
St. Leonards	− 85	− 89	− 74·7	− 79·5	67 44·5	67 49·7	−05·2
Llandovery	+ 76	− 19	+ 10·1	+ 04·0	69 09·3	69 03·2	+06·1
Stonyhurst	+ 28	+ 91	+ 58·0	+ 59·4	69 57·2	69 58·6	−01·4
Glangwnna	+ 92	+ 48	+ 59·6	+ 46·7	69 58·8	69 45·9	+12·9
Teignmouth	+ 68	−107	− 56·1	− 49·7	68 03·1	68 09·5	−06·4
Torquay	+ 70	−112	− 57·0	− 52·3	68 02·2	68 06·9	−04·7
Mt. Edgecombe	+ 96	−119	− 52·8	− 51·2	68 06·4	68 08·0	−01·6
Penjerrick	+131	−132	− 52·6	− 51·9	68 06·6	68 07·3	−00·7
Lew Trenchard	+ 95	−101	− 43·1	− 40·8	68 16·1	68 18·4	−02·3
Broome Park	− 52	− 66	− 59·2	− 49·4	68 00·0	68 09·8	−09·8
Jordan Hill	+ 89	+212	+150·3	+143·0	71 29·5	71 22·2	+07·3
Fern Tower	+ 71	+242	+144·2	+157·1	71 23·4	71 36·3	−12·9
Jardine Hall	+ 59	+170	+104·2	+112·3	70 43·4	70 51·5	−08·1
Scarborough	− 46	+117	+ 58·8	+ 60·0	69 58·0	69 59·2	−01·2
Cambridge	− 66	− 7	− 16·5	− 17·2	68 42·7	68 42·0	+00·7
Llandovery	+ 76	− 19	+ 12·0	+ 4·0	69 11·2	69 03·2	+08·0
Stackpole Court	+120	− 42	+ 00·7	− 00·9	68 59·9	68 58·3	+01·6
Cawston	−104	+ 27	− 03·0	− 04·7	68 55·3	68 54·5	+00·8
Margate	−115	− 57	− 51·5	− 56·6	68 07·7	68 02·6	+05·1
Folkestone	−107	− 75	− 68·2	− 65·6	67 51·0	67 53·6	−02·6
Cleethorpe	− 60	+ 72	+ 34·2	+ 30·7	69 33·4	69 29·9	+03·5
Lowestoft	−125	+ 10	− 16·7	− 19·0	68 42·5	68 40·2	+02·3
Cawston	−104	+ 27	− 03·1	− 04·7	68 56·1	68 54·5	+01·6
Cromer	−108	+ 36	+ 00·1	− 00·2	68 59·3	68 59·0	+00·3
Kew	− 52	− 51	− 37·8	− 40·5	68 21·2	68 18·7	+02·5

The direction of the isoclinal lines in England thus found for January 1, 1860, is from N. 71° 22′ E. to S. 71° 22′ W. The direction found in the previous survey (by observations at 132 stations by five observers) was from N. 65° 05′ E. to S. 65° 05′ W. (Brit. Assoc. Report, 1838, pp. 85 and 86). The central geographical positions are only a few miles distant from each other, being respectively 52° 38′ N., and 2° 07′ W. in 1837, and 52° 20′ N., and 1° 41′ W. in 1860. From the large amount of the difference in the direction of the lines at the two epochs (6° 17′), it is scarcely possible to doubt that in the interval between 1837 and 1860 a real change has taken place in this respect, and that the isoclinal lines passing across England have increased the angle which they make with the geographical meridians; a change implying that in the interval the secular diminution of the dip has been greater on the *West* than on the *East* side of the island.

In the survey of 1837, r was found $=0'·575$, and in that of $1860=0'·624$; the geographical distance between the lines has therefore increased in the interval in the proportion of 0′·624 to 0′·575; a change implying that the secular diminution of the dip has been greater in the *Southern* than in the *Northern* parts of England.

The difference in the rate of secular change on the east and on the west sides of England may be also shown *directly* by the comparison of the observations at two stations, Margate and Lew Trenchard, one on the east and the other on the west side; the stations were common to both surveys, the observer being the same at the two periods and the localities identical: the instrument employed in the earlier survey was a circle and two needles by Gambey, free from any appreciable error, and in the later survey, No. 30 and its two needles already described: the results were as follows:—

Margate.		Lew Trenchard.	
Lat. 51° 23′ N., Long. 1° 23′ E.		Lat. 50° 39′ N., Long. 4° 11′ W.	
Nov. 9, 1837	69° 02′·9	July 30, 1838	69° 19′·0
Oct. 5, 1860	68° 05′·9	July 9, 1859	68° 17′·4
Secular change in 22·9 years	57′·0	Secular change in 21 years	1° 01′·6
Annual change	2′·49	Annual change............	2′·93

This comparison shows that the mean annual secular change in the interval between the surveys was a decrease of 2′·49 at Margate on the east coast, and of 2′·93 at Lew Trenchard on the borders of Devonshire and Cornwall.

The amount of the difference in the rate of secular change on the east and west coasts corresponding to the change in the value of u, may be further and more fully exemplified by comparing the values of the dip at the two epochs 1837 and 1860 at Lowestoft on the extreme east of England, and at the Land's End at the extreme west; the values in 1837 being taken from the map of the isoclinal lines for January 1837 accompanying the report of the survey of that epoch, and those in 1860 being computed by the formula obtained by the survey of 1860.

	Lowestoft. Lat. 52° 30′ N., Long. 1° 45′ E.	Land's End. Lat. 50° 05′ N., Long. 5° 40′ W.
Dip in the Isoclinal map of 1837	° ′ 69 34·5	° ′ 69 21·0
Dip in January 1860, computed by the formula $\theta=68° 59{\cdot}2+0'{\cdot}1993\,a+0'{\cdot}5911\,b$	68 40·2	68 10·0
Secular change in 23 years	54·3	1 11·0
Annual change	2·36	3·09

If we now bring together the values of the annual secular change during the 23 years preceding 1860 as shown by these four comparisons, placing them in order from East to West across our island, and introducing in its proper place 2′·63, the annual secular change at Kew in the 21 years preceding 1859 as known from other sources (Proceedings of the Royal Society, vol. xi. p. 158), we have as follows:—

Lowestoft...............	′ 2·36	Lew Trenchard	′ 2·93
Margate	2·49	Land's End..............	3·09
Kew.....................	2·63		

The increase in proceeding from east to west is shown consistently. The annual values derived from determinations including intervals of above 20 years, are of course *mean* values. The surveys furnish no direct means of judging whether the secular change has been *uniform* or otherwise at any of the stations. At one of the stations only, *i. e.* Kew, we have reason to believe, from the observations recorded in the 'Proceedings of the Royal Society' referred to above, that the change has been uniform during the whole period from 1837 to 1860 (and also for several years preceding 1837); but we are not entitled to assume a similar uniformity at any of the other stations.

Proceeding now to the increase in the value of r in the interval between the two surveys,—the difference in the rate of secular change of dip in the northern and southern parts of England which is implied thereby may be similarly shown, by comparing the dips in 1837 and 1860 at two geographical positions, one in the extreme north, and the other in the extreme south of England. Taking as the northern station the intersection in the map of January 1837 of the isoclinal line of 71° 30′ with the parallel of 55° N. latitude, which takes place in the longitude of 3° 00′ W.,—and for the southern station the intersection of the isoclinal line of 69° in the same map with the parallel of 51°, which takes place in 0° 07′ East longitude,—and comparing these values with the values computed for January 1860 by the formula corresponding to that epoch, we have—

	North Geog. Position. Lat. 55°, Long. 3° 00′ W.		South Geog. Position. Lat. 51°, Long. 0° 07′ E.
Dip in the map corresponding to January 1, 1837	71° 30′·0	....	69° 00′·0
Dip on January 1, 1860, computed by the formula $\theta = 68° 59'{\cdot}2 + 0'{\cdot}1993a + 0'{\cdot}5911b$	70° 42′·8	....	67° 58′·4
Secular change in 23 years	47′·2	....	1° 01′·6
Annual change..........................	2′·05	....	2′·68

The comparison shows that the mean annual secular change in the interval of 23 years between the surveys was 2′·05 on the northern border of England, and 2′·68 at a station on the south coast. Thus it is seen that the annual rate of decrease of dip has varied in different parts of England in proceeding from east to west, from 2′·36 at Lowestoft to 3′·09 at the Land's End; and in proceeding from north to south from 2′·05 at a position in 55° to 2′·68 at a position in 51° N. latitude.

In viewing the map in which the isoclinal lines for 1837 and 1860 are represented in comparison with each other (Pl. VIII.), it is seen that there are three points where the amount of secular change in the interval must have been the same, viz. the three points where the lines of 68°, 69°, and 70° in 1837 intersect respectively with those of 69°, 70°, and 71° in 1860; since at each of these points the mean annual change must have been (60′ ÷ 23 years =) 2′·62. These three points are seen to be in a curved line which crosses England from the vicinity of Folkestone to the Irish Channel, and would impinge upon the east coast of Ireland a few miles north of Dublin. Kew, also, where the mean annual decrease of the dip in the same interval has been 2′·63, is as nearly as may be on the same line. At all stations north and east of the line the mean annual secular change in the 23 years has been less than 2′·62, and at all stations south and west of the line greater than 2′·62. In a preceding page we have the mean annual change at four stations (Lowestoft, Margate, Lew Trenchard, and Land's End) situated at points on the east and west sides of England, and at two geographical positions (55° N. and 3° W., and 51° N. and 0° 07′ E.) at north and south points. An intercomparison of the respective values of annual change at these six localities with 2′·62, and of their geographical distances from the aforesaid line of 2′·62 measured in every case on a perpendicular to that line, shows that an increase of 0′·1 in the annular secular change for every 30 geographical miles towards the N.E., and a decrease of 0′·1 for every 30 geographical miles towards the S.W., will represent very approximately the observed values. We are thus furnished with a scale by which the variation in the mean rate of the secular decrease of the dip in different parts of England in the interval between the two surveys may be approximately assigned; the limits being an annual decrease of 3′·1 at the Land's End, and of 2′·0 at Berwick. If we should permit ourselves to extend the same scale of variation to the north of Scotland, we should find the mean annual decrease reduced to 1′·6. The very small corrections required to reduce the results of the observations of the present survey to a common epoch (January 1, 1860), as shown in Table II. p. 257, have been estimated in accordance with this scale of variation: the whole of the observations were made within two years of the common epoch.

The line which has been indicated as connecting the intersections of the isoclinals of 68°, 69°, and 70° of 1837 with those of 69°, 70°, and 71° of 1860, is marked on the map by a faintly dotted line. It is in fact a line composed of nodal points, on which the isoclinals passing through them may be conceived to have turned, as on pivots, in the interval of 23 years, and (irrespective of their common and uniform movement of translation to the north) to have undergone a change of *direction*, becoming more southerly on the eastern side of the nodal line, and more northerly on its western side.

Division II.—*Intensity of the Magnetic Force.*

For the purpose of ascertaining the position, direction, and distance apart of the isodynamic lines, or lines of equal Total Force, two methods were employed, viz. (a) the determination at different stations of the values in *absolute measure* of the *horizontal* component of the force, which values, being combined with the dip of the needle observed at the same time and place, give the absolute values of the total force; and (b) the determination of the variations of the total force itself at the different stations, by observing the positions of equilibrium of a dipping-needle between the action of the earth's magnetism and that of a small constant weight with which the needle is loaded. It may be convenient to discuss these methods and their results separately; and with this view we may commence with the determinations of the absolute value of the horizontal component of the force.

a. *Horizontal Force in Absolute Measure.*—A full description of the instruments, and of the method employed in these experiments, is given in App. I. of the article on "Terrestrial Magnetism" in the 3rd edition of the 'Manual of Scientific Inquiry,' published under the authority of the Admiralty. The collimator magnet employed as a deflector was numbered 5, and was used throughout the experiments. Its moment of inertia (K), including the suspending stirrup and other appendages, was determined at Kew, by the late Mr. Welsh, in June 1858, by the mean of experiments with three cylinders B, C, and D, of which the weights and dimensions were respectively as follows—

	in.	in.	grs.
B	length 4·0193;	diam. 0·3917;	weight 1029,62,
C	length 4·0488;	diam. 0·3929;	weight 1044,42,
D	length 4·0131;	diam. 0·3916;	weight 1029,71,

whence K was found $=0·73100$ at 60° Fahr.; and the log of $\pi^2 K=$

1·72513 at 30° Fahr. 1·72531 at 60° Fahr. 1·72549 at 90° Fahr.
1·72519 at 40° Fahr. 1·72537 at 70° Fahr.
1·72525 at 50° Fahr. 1·72543 at 80° Fahr.

The correction for the decrease of the magnetic moment of No. 5, produced by an increase of 1° Fahr. $=(q)=0·00011\,(t_0-t)+·0000006\,(t_0-t)^2$, t_0 being the observed temperature, and $t=45°$. The induction coefficient $(\mu)=0·000252$. These were both determined at Kew by the same careful experimentalist. The angular value of one scale-division of the vibration apparatus $=2'·27$. The graduation of the deflection bar, compared with the verified standard measure of the Kew Observatory, was without error within the limits which were used. The rate of the chronometer and the arc of vibration were too small throughout the experiments to require corrections to be applied on their account. The constant P, depending upon the distribution of magnetism in the deflecting and suspended magnets (the same magnets having been used throughout), was determined by the experiments in Table IV. made at Kew by Mr. Chambers:—

TABLE IV.—Deflections with Collimator 5 at distances 0·9 ft. and 1·2 ft. to determine the value of P. Observed by Mr. Chambers.

Distance 0·9 ft. $=r$; $1+\frac{2\mu}{r_0^3}=1·00069$; $t=45°$.				Distance 1·2 ft. $=r_1$; $1+\frac{2\mu}{r_0^3}=1·00029$; $t=45°$.			
1859.	Temp.	Deflections.	Log $\frac{m'}{X'}$.	1859.	Temp.	Deflections.	Log $\frac{m'}{X'}$.
	°	° ′ ″			°	° ′ ″	
Feb. 5......	52·6	21 11 45	9·12046	Feb. 5......	52·6	8 45 52	9·11984
„ 5......	53·3	21 13 34	9·12145	„ 5......	53·3	8 52 00	9·12489
„ 5......	53·1	21 15 00	9·12155	„ 5......	53·1	8 50 25	9·12357
„ 7......	41·4	21 15 24	9·12096	„ 7......	41·4	8 48 15	9·12104
„ 7......	44·8	21 14 16	9·12076	„ 7......	44·8	8 48 09	9·12118
„ 7......	47·3	21 13 34	9·12070	„ 7......	47·3	8 47 56	9·12117
Mar. 2......	56·5	21 09 42	9·12007	Mar. 2......	56·5	8 46 04	9·12027
„ 4......	63·5	21 07 45	9·11995	„ 4......	63·5	8 45 26	9·12028
Mean .... log A=9·12073				Mean .... log A′=9·12153			

$$\text{Whence } P=(A-A')\div\left(\frac{A}{r^2}-\frac{A'}{r_1^2}\right)=-·00337.$$

The experiments detailed in Tables V. and VI. were made with Collimator No. 5, in June 1858, and in January and March 1859, by Messrs. Welsh and Chambers, to determine the value in British units of the magnetic force at the Kew Observatory, adopted as the base station of the Survey.

TABLE V. (*see opposite page*).

TABLE VI.—Conclusions from Table V.

Date.	Distance.	X.	m.	θ.	ϕ.	Observers.
	ft.			° ′		
1858. June 17 ...	0·9	3·7894	·5178	68 23·3	10·289	Mr. Welsh.
June 18 ...	0·9	3·7847	·5177	68 23·3	10·276	
June 18 ...	0·9	3·7858	·5179	68 23·3	10·279	
1859. January 15	1·0	3·7918	·5121	68 22·4	10·288	Mr. Chambers.
January 15	1·0	3·7894	·5118	68 22·4	10·282	
January 19	0·9	3·7880	·5126	68 22·4	10·278	
January 19	1·2	3·7930	·5114	68 22·4	10·292	
January 20	1·2	3·7993	·5120	68 22·4	10·308	
January 20	0·9	3·7910	·5123	68 22·4	10·286	
March 2...	0·9	3·7933	·5020	68 22·4	10·292	
March 2...	1·2	3·7966	·5022	68 22·4	10·301	
March 4...	1·2	3·7957	·5019	68 22·4	10·299	
March 4...	0·9	3·7953	·5024	68 22·4	10·298	
Mean corresponding to January 1859					10·290	

$$X=\sqrt{mX\div\frac{m}{X}};\quad m=\sqrt{mX\,.\,\frac{m}{X}};\quad \phi=X\sec\theta.$$

θ in June 1858 from 115 observations at Kew (68° 23′·2 on July 1, 1858).
θ in January and March 1859, from 54 observations at Kew in those months (Proceedings of the Royal Society, vol. xi. pp. 150, 151 and 152).

Table V.

Date.	Experiments of Deflection.				Experiments of Vibration.					Observer.
	$\frac{m}{X}=\frac{1}{2}r^3\sin u\left\{1+\frac{2\mu}{r^3}+q(t_0-t)\right\}\left\{1-\frac{P}{r^2}\right\}.$				$mX=T^2\left\{1+\frac{H}{F}-q(t_0-t)+\mu\frac{X}{m}\right\}.$					
	Dist. $=r$.	Temp. $=t_0$.	Deflection $=u$.	Log $\frac{m}{X}$.	No. of Vibrs.	Time $=$T.	Temp. $=t_0$.	$\frac{H}{F}$.	Log mX.	
1858.	ft.	°	° ′ ″			s	°			
June 17	0·9	73·2	21 48 23	9·13560	250	5·2021	74·4	·00273	0·29275	Mr. Welsh.
,, 17	0·9	73·2	21 48 34		250	5·2025	73·2	·00273		
,, 18	0·9	62·7	21 52 45		250	5·2015	66·8	·00215	0·29211	Mr. Welsh.
				9·13604	250	5·2032	67·4	·00215		
					250	5·2059	73·6	·00215	0·29239	Mr. Welsh.
,, 18	0·9	62·7	21 52 10		250	5·2061	73·8	·00215		
1859.										
Jan. 15	1·0	47·0	15 36 59		150	5·2165	43·6	·00312	0·28820	Mr. Chambers.
				9·13052	150	5·2169	44·4	·00312		
					150	5·2232	48·4	·00297	0·28765	Mr. Chambers.
,, 15	1·0	48·0	15 36 20		150	5·2207	48·0	·00297		
,, 19	0·9	48·7	21 39 19	9·13136	160	5·2200	47·4	·00224	0·28816	Mr. Chambers.
,, 19	0·9	49·5	21 42 03		160	5·2212	48·0	·00224		
,, 19	1·2	49·9	8 56 42	9·12974	160	5·2305	52·3	·00110	0·28768	Mr. Chambers.
,, 19	1·2	50·4	8 57 17		160	5·2255	51·9	·00110		
,, 20	1·2	46·8	8 56 58	9·12958	150	5·2106	46·3	·00411	0·28897	Mr. Chambers.
,, 20	1·2	47·4	8 57 07		150	5·2102	46·1	·00411		
,, 20	0·9	48·8	21 38 34	9·13074	150	5·2188	50·2	·00365	0·28822	Mr. Chambers.
,, 20	0·9	49·4	21 38 53		150	5·2162	50·2	·00365		
Mar. 2	0·9	56·5	21 09 42	9·12189	150	5·2738	56·5	·00202	0·28000	Mr. Chambers.
					150	5·2737	56·8	·00202		
,, 2	1·2	56·5	8 46 04	9·12131	150	5·2750	57·4	·00203	0·27991	Mr. Chambers.
					150	5·2740	57·3	·00203		
,, 4	1·2	63·5	8 45 26	9·12132	150	5·2768	64·4	·00105	0·27995	Mr. Chambers.
					150	5·2777	64·4	·00104		
,, 4	0·9	63·5	21 07 45	9·12177	150	5·2803	64·4	·00135	0·28024	Mr. Chambers
					150	5·2772	64·4	·00135		

Table VII. contains the details of the experiments of Deflection and Vibration, made with Collimator No. 5, at the several stations of the Survey, and Table VIII. the conclusions derived from them. These experiments were all made by myself.

TABLE VII.

Station.	Date.	Experiments of Deflection. $\frac{m}{X}=\frac{1}{2}r^3 \sin u \left\{1+\frac{2\mu}{r^3}+q(t_0-t)\right\}1-\frac{P}{r_2}\}$. r.	t_0.	u.	Log $\frac{m}{x}$.		Experiments of Vibration. $mX=T^2\left\{1+\frac{H}{T}-q(t_0-t)+\mu\frac{X}{m}\right\}$. Date.	No. of vibrations	Time = T.	t_0.	$\frac{H}{F}$.	Log mX.
	1858.	ft.	°	° ′ ″			1858.			°		
St. Leonards	July 3......	0·9	58·4	21 24 27	9·12680	....	July 3 ...	250	5·1470	58·4	·00380	0·30043
"	" 3......	0·9	58·4	21 24 17								
Llandovery	Aug. 9 ...	0·9	69·0	22 20 25	9·14828	9·14814	Aug. 10 ...	250	5·2893	71·2	·00380	0·27765
"	" 9 ...	0·9	69·9	22 29 12	9·14797		" 10 ...	250	5·2903	73·2	·00380	
							" 10 ...	250	5·2910	74·0	·00380	0·27793
							" 10 ...	250	5·2872	74·2	·00380	
"	Aug. 11 ...	0·9	69·8	22 29 30	9·14805		" 10 ...	250	5·2873	77·0	·00380	0·27865
"	" 11 ...	0·9	73·8	22 29 10	9·14827		" 10 ...	250	5·2847	76·6	·00380	
"	" 24 ...	0·9	70·0	22 26 32	9·14738	9·14742	" 24 ...	250	5·2888	68·0	·00400	0·27745
							" 24 ...	250	5·2893	68·0	·00400	
"	" 24 ...	0·9	70·0	22 26 53	9·14746		" 24 ...	250	5·2889	68·0	·00400	
"	Sept. 13 ...	1·1	74·5	12 04 45	9·14713	9·24718						
"	" 13 ...	0·9	75·4	22 25 58	9·14740		Sept. 13 ...	462	5·2998	79·0	·00428	0·27672
"	" 13 ...	1·0	77·5	16 08 46	9·14700		" 13 ...	250	5·2940	77·0	·00428	
Stonyhurst..............	Oct. 1 ...	0·9	54·8	23 13 28	9·16012	....	Oct. 1 ...	250	5·3853	54·8	·00406	0·26088
"	" 1 ...	0·9	53·9	23 13 37			" 1 ...	250	5·3852	54·7	·00406	
Glangwnna..............	" 6 ...	0·9	49·8	23 09 28	9·15848	....	" 6 ...	250	5·3693	51·5	·00295	0·26340
"	" 6 ...	0·9	49·8	23 08 49			" 6 ...	300	5·3731	51·4	·00295	
"	" 7 ...	0·9	48·1	23 01 41	9·15610	....	" 7 ...	250	5·3803	53·2	·00295	0·26226
"	" 7 ...	0·9	47·8	23 01 25			" 7 ...	350	5·3778	53·2	·00295	

	1859.					1859.					
Teignmouth	June 17	0·9	65·5	20 46 02	9·11481	June 18	350	5·2584	72·0	·00242	0·28377
"	" 17	0·9	67·5	20 45 33		" 18	350	5·2520	69·0	·00242	
"	" 20	0·9	61·6	20 44 15	9·11386	" 20	350	5·2660	64·2	·00219	0·28169
Penjerrick	" 30	0·9	62·0	20 43 12	9·11357	" 30	300	5·2600	64·0	·00241	0·28254
"	July 1	0·9	65·2	20 40 38	9·11292	July 1	350	5·2726	65·2	·00241	0·28054
						" 1	350	5·2678	64·6	·00241	0·28034
Lew Trenchard	" 11	0·9	74·0	20 43 36	9·11458	" 11	350	5·3003	79·0	·00241	0·27705
Jardine Hall	Oct. 8	0·9	63·7	22 47 51	9·15315	Oct. 7	400	5·5780	66·7	·00251	0·23228
						" 7	350	5·5713	64·8	·00251	
Scarborough	" 12	0·9	......	....	9·13955	" 12	400	5·4896	61·4	·00251	0·24529
	1860.					1860.					
Cambridge	May 17	0·9	60·0	20 57 45	9·11824	May 17	250	5·3903	62·	·00266	0·26297
"	" 17	0·9	60·0	20 57 51		" 17	300	5·3670	60·	·00266	
Llandovery	July 16	0·9	63·0	21 07 36	9·12144	July 16	300	5·4367	67·0	·00360	0·25360
"	" 16	0·9	62·8	21 05 52		" 16	300	5·4367	68·4	·00360	
Stackpole Court	Aug. 21	0·9	57·2	20 49 58	9·11543	Aug. 22	350	5·4012	63·0	·00090	0·25953
"	" 22	0·9	58·5	20 49 33		" 22	450	5·4087	63·0	·00090	
Cawston	Sept. 11	0·9	56·1	20 58 46	9·11826	Sept. 11	450	5·4158	59·0	·00227	0·25693
"	" 11	0·9	56·4	20 57 08	9·11776	" 11	350	5·4144	56·7	·00227	0·25717
Margate	Oct. 6	0·9	59·5	20 15 43	9·10398	Oct. 6	350	5·3419	60·9	·00183	0·26929
"	" 6	0·9	59·8	20 14 47		" 6	450	5·3400	59·8	·00183	
Folkestone	" 9	0·9	52·0	20 04 38	9·09935	" 9	450	5·3154	52·0	·00226	0·27284
"	" 9	0·9	53·4	20 02 54		" 9	450	5·3131	49·6	·00226	
	1861.					1861.					
Cleethorpe	Sept. 17	0·9	57·0	21 07 05	9·12112	Sept. 17	460	5·5204	59·0	·00195	0·24053
"	" 17	0·9	57·0	21 07 04		" 17	360	5·5202	61·0	·00195	
"	" 17	0·9	57·0	21 06 47							
Lowestoft	" 24	0·9	59·5	20 18 44	9·10518	" 23	420	5·4333	57·0	·00200	0·25410
"	" 24	0·9	59·5	20 19 24		" 24	420	5·4383	59·0	·00210	0·25340
Cawston	" 27	0·9	60·0	20 32 19	9·11000	" 27	420	5·4673	61·0	·00210	0·24886
"	" 27	0·9	61·0	20 34 39		" 27	400	5·4687	62·0	·00210	
"	" 27	0·9	61·0	20 33 15							
Cromer	Oct. 5	0·9	67·5	20 36 39	9·11179	Oct. 3	420	5·4741	61·3	·00252	0·24839
"	" 5	0·9	67·5	20 37 54		" 3	360	5·4663	61·3	·00252	
"	" 5	0·9	68·5	20 37 42		" 3	360	5·4702	62·0	·00252	
						" 4	420	5·4714	69·2	·00252	

TABLE VIII.—Conclusions from Table VI. and VII.

Stations.	Date.	X.	m.	θ.	φ.
				° ′	
Kew	1859. January	......	......	......	10·290
St. Leonards	1858. July	3·8670	·5171	67 48·5	10·225
Llandovery	Aug. & Sept.	3·6722	·5161	69 13·0	10·349
Stonyhurst	October	3·5512	·5135	70 00·2	10·385
Glangwnna	October	3·5708	·5130	70 02·0	10·448
Teignmouth	1859. June	3·8388	·4995	68 04·7	10·283
Penjerrick	June & July	3·8371	·4979	68 08·2	10·303
Lew Trenchard	July	3·8128	·4964	68 17·4	10·308
Jardine Hall	October	3·4638	·4929	70 43·9	10·496
Scarborough	October	3·5717	·4925	70 58·5	10·431
Cambridge	1860. May	3·7356	·4905	68 41·9	10·280
Llandovery	July	3·6820	·4870	69 09·7	10·350
Stackpole Court	August	3·7330	·4869	68 58·2	10·401
Cawston	September	3·7112	·4870	68 53·7	10·307
Margate	October	3·8252	·4860	68 05·9	10·255
Folkestone	October	3·8614	·4854	67 49·0	10·227
Cleethorpe	1861. September	3·6283	·4795	69 29·7	10·356
Lowestoft	September	3·7521	·4780	68 38·6	10·303
Cawston	September	3·7105	·4780	68 52·1	10·292
Cromer	October	3·7008	·4787	68 55·3	10·291

$X=\sqrt{mX \div \frac{m}{X}}$; $m=\sqrt{mX \cdot \frac{m}{X}}$; $\phi = X \sec\theta$; θ from Table I.

b. *Variations of the Total Force determined by the Statical Method.*—This method is described in the 'Manual of Terrestrial Magnetism,' 3rd edition, pp. 27 & 28, section B. The Dip Circle No. 30 was furnished with two additional needles, Nos. 3 and 4, the poles of which were at no time reversed or disturbed. No. 3 was an ordinary dipping-needle, and No. 4 a similar needle loaded with a small fixed and constant weight, deflecting it from its natural position in the magnetic direction. The frame carrying the microscopes was fitted to receive and retain No. 4 securely in a constant position when used to deflect No. 3.

The experiment consists of two processes: the first being the observation of the position of equilibrium of No. 3 between the action of the earth's magnetism and that of No. 4 used as a deflector; the north pole of No. 4 being directed alternately towards the (magnetic) north and south: and the second process being the observation of the position of equilibrium of No. 4 between the action of the earth's magnetism and that of the small fixed and constant weight with which it is loaded.

By the first process we obtain the inclination to the horizon of No. 3 when deflected by No. 4 $=u_1=$ half the difference between the readings (in a single position of the circle and needle) with the north pole of No. 4 directed alternately north and south; and by the second process we obtain the inclination to the horizon of the loaded needle observed in the four positions of the circle and needle $=\eta$. Then $\theta-\eta=u$ is the deviation of the loaded needle from the position due to the earth's magnetism alone, θ being the mean dip observed with needles 1 and 2 at the same time and place.

We have then the following expression for the total force (ϕ) at each station,

$$\phi=A\sqrt{\frac{\cos\eta}{\sin u \sin u_1}},$$

where A is a constant obtained by the formula

$$A=\frac{X}{\cos\theta}\sqrt{\frac{\sin u \sin u_1}{\cos\eta}},$$

from observations made at a base station where X and θ have been carefully determined.

The Observatory at Kew having been taken as a base station, the experiments detailed in Tables IX. and X. were kindly made at my request by Messrs. Stewart and Chambers in January 1859 and October 1860, to determine the value of the constant A at those epochs.

Table IX.—Observations made at the Kew Observatory by Mr. Chambers in January 1859, with needles 3 and 4 of Circle 30, to determine the value of the constant A.

X=10·290 (Tables V. & VI.). $\theta=68°\ 22'\ 18''$ (Proceedings of the Royal Society, vol. xi. p. 151).

Date.	η.	u.	u_1.
	° ′ ″	° ′ ″	° ′ ″
January 13	−17 38 00	86 00 18	30 27 23
" 13	−17 38 17	86 00 35	30 27 50
" 21	−17 45 22	86 07 40	30 25 02
" 21	−17 55 30	86 17 48	30 25 09
" 22	−17 53 54	86 16 12	30 26 30
" 22	−18 07 49	86 30 07	30 26 34
Means	−17 49 49	86 12 07	30 26 25
Whence A= log 0·87498.			

Table X.—Observations made at the Kew Observatory by Mr. Stewart in October 1860, with needles 3 and 4 of Circle 30, to determine the value of the constant A.

X=10·290 (Tables V. & VI.). $\theta=68°\ 19'{\cdot}6$ (Proceedings of the Royal Society, vol. xi. p. 154).

Date.	η.	u.	u_1.
	° ′	° ′	° ′
October 17.........	−22 38	90 57·6	29 23·7
" 17.........	−22 45	91 04·6	29 24·2
" 17.........	−22 45	91 04·6	29 21·5
" 17.........	−22 42	91 01·6	29 21·7
" 18.........	−22 34	90 53·6	29 24·5
" 18.........	−22 37	90 56·6	29 24·5
Means	−22 40·2	90 59·8	29 23·3
Whence A= log 0·87524.			

It appears, therefore, that the constant A was substantially the same at an early stage and at the close of the survey experiments. The value employed has been A= log 0·87516.

Table XI. exhibits the results of the statical determination of the Total Force at the stations of the survey where that method was employed.

Table XI.

Station.	Date.	Temp.	η.	θ.	u'.	u.	φ	
	1858.	°			° '			
St. Leonards	June 23	82	−18 41·2	67 48·5	30 40·6	86 29·7	10·238	10·224
"	" 23	82			30 35·3			
"	" 26	78	−18 41·4	67 48·5	30 48·9	86 29·9	10·210	
"	" 26	78			30 49·5			
"	July 5	60	−18 50·9	67 48·5	30 40·8	86 39·4	10·225	
Llandovery	" 22	61	−16 53·5	69 13·0	30 11·2	86 06·5	10·360	10·378
"	Aug. 7	68	−17 10·1	69 13·0	29 58·4	86 23·1	10·385	
"	Sept. 7	60	−16 31·8	69 13·0	30 05·1	85 44·8	10·389	
Glangwnna	Oct. 9	55	−15 13·2	70 02·0	30 02·5	85 15·2	10·433	10·433
	1859.							
Teignmouth	June 15	64	−19 11·9	68 04·7	30 17·0	87 15·6	10·272	10·277
"	" 16	60	−18 49·1	68 04·7	30 19·1	86 53·8	10·280	
"	" 16	60	−18 57·9	68 04·7	30 17·1	87 02·6	10·280	
Torquay	" 24	61	−19 25·1	68 03·7	30 25·6	87 28·8	10·242	10·242
Mount Edgecombe	" 25	60	−18 56·4	68 07·9	30 20·4	87 04·3	10·272	10·272
Penjerrick	" 29	63	−18 59·7	68 08·2	30 16·2	87 08·1	10·281	10·281
"	" 29	63	−19 00·1					
Lew Trenchard	July 8	64	−18 32·4	68 17·5	29 57·8	86 49·9	10·344	10·344
Broome Park	" 21	73	−19 42·3	68 04·2	30 21·2	87 42·0	10·245	10·245
"	" 21	73	−19 39·3					
Fern Tower	Oct. 3	57	−13 56·9	71 23·9	29 00·6	85 28·5	10·626	10·626
"	" 3	57	−14 12·2					
Jardine Hall	" 5	55	−15 11·6	70 43·9	29 32·6	85 55·5	10·508	10·508
Scarborough	" 12	53	−17 17·1	69 58·5	29 44·6	87 15·3	10·414	10·414
"	" 12	53	−17 16·5					
	1860.							
Llandovery	Aug. 1	61	−18 23·8	69 09·7	29 53·2	87 33·5	10·357	10·357
Stackpole Court	" 21	59	−17 33·0	68 58·2	29 52·6	86 31·2	10·388	10·388
Cawston	Sept. 10	60	−19 02·0	68 53·7	29 59·5	87 55·7	10·320	10·317
"	" 10	60	−18 56·8	68 53·7	29 59·5	87 54·5	10·322	
"	" 13	60	−18 56·6	68 53·7	30 03·8	87 49·7	10·310	
Margate	Oct. 5	58	−19 37·8	68 05·9	30 18·7	87 47·3	10·251	10·251
"	" 5	58	−19 45·0					

$\phi = A\sqrt{\frac{\cos\eta}{\sin u \sin u'}}$; A = log 0·87516 determined at Kew. θ from Table I.

The values of the total force at the several stations derived by the absolute and by the statical methods are collected in Table XII., together with the latitudes and longitudes of the stations.

Table XII.

Station.	Lat. N.	Long. W.	Total Force $=\phi$. Absolute Method.	Statical Method.	Adopted.
	° ′	° ′			
Kew	51 29	0 18	10·290	10·290	10·290
St. Leonards	50 51	−0 33	10·225	10·224	10·225
Llandovery	52 01	3 45	10·349	10·378	10·363
Stonyhurst	53 51	2 28	10·385	....	10·385
Glangwnna	53 08	4 14	10·448	10·433	10·440
Teignmouth	50 33	3 30	10·283	10·277	10·280
Torquay	50 28	3 32	....	10·242	10·242
Mount Edgecombe	50 21	4 11	....	10·272	10·272
Penjerrick	50 08	5 07	10·303	10·281	10·292
Lew Trenchard	50 39	4 11	10·308	10·344	10·326
Broome Park	51 14	0 18	....	10·245	10·245
Fern Tower	56 22	3 50	....	10·626	10·626
Jardine Hall	55 10	3 24	10·496	10·508	10·502
Scarborough	54 17	0 23	10·431	10·414	10·423
Cambridge	52 13	−0 06	10·280	....	10·280
Llandovery	52 01	3 45	10·350	10·357	10·354
Stackpole Court	51 38	4 55	10·401	10·388	10·395
Cawston	52 47	−1 12	10·307	10·317	10·312
Margate	51 23	−1 23	10·255	10·251	10·253
Folkestone	51 05	−1 10	10·227	....	10·227
Cleethorpe	53 32	0 00	10·356	....	10·356
Lowestoft	52 30	−1 45	10·303	....	10·303
Cawston	52 47	−1 12	10·292	....	10·292
Cromer	52 56	−1 17	10·291	....	10·291

Table XIII.—Differences in the values of ϕ by the Absolute and Statical Methods at Stations where both methods were employed.

Station.	Absolute—Statical.	Station.	Absolute—Statical.
St. Leonards	+·001	Jardine Hall	−·012
Llandovery	−·029	Scarborough	+·017
Glangwnna	+·015	Llandovery	−·007
Teignmouth	+·006	Stackpole Court	+·013
Penjerrick	+·022	Cawston	−·010
Lew Trenchard	−·036	Margate	+·004

Sum of the + differences, ·078; sum of the − differences, ·094; excess of − differences, ·016 in 12 determinations; or ·001 on the average, being about one ten-thousandth of the whole force.

The mean latitude of the 24 stations in Table XII. is 52° 13′, and the mean longitude 1° 38′ W. The mean force at the central position is $10·332=\phi'$. The stations, and the adopted values of ϕ, contained in Table XII. being combined in the usual manner, give (u) the angle which the isodynamic lines make with the meridian $=-57°35'·7$, (or their direction is from N. 57° 35′·7 E. to S. 57° 35′·7 W.;) and r, or the rate of increase of the total force is a normal direction $=\cdot 00102$ (in British units) for each geographical mile. The formula for computing the total force at each station (ϕ) is

$$\phi=10\cdot 332+\cdot 000557\,a+\cdot 000878\,b,$$

a and b being coordinates of the distance of the station from the central position, expressed in geographical miles.

The observed and computed values of the force at the several stations are shown in Table XIV.

TABLE XIV.

Station.	ϕ.		Differences. Observed— Computed.
	Observed.	Computed.	
Kew	10·290	10·266	+·024
St. Leonards	10·225	10·214	+·011
Llandovery	10·363	10·363	·000
Stonyhurst	10·385	10·435	—·050
Glangwnna	10·440	10·433	+·007
Teignmouth	10·280	10·283	—·003
Torquay	10·242	10·281	—·039
Mount Edgecombe	10·272	10·288	—·016
Penjerrick	10·292	10·297	—·005
Lew Trenchard	10·326	10·304	+·022
Broome Park	10·245	10·252	—·007
Fern Tower	10·626	10·591	+·035
Jardine Hall	10·525	10·521	+·004
Scarborough	10·423	10·416	+·007
Cambridge	10·280	10·296	—·016
Llandovery	10·354	10·363	—·009
Stackpole Court	10·395	10·369	+·026
Cawston	10·312	10·305	+·007
Margate	10·253	10·225	+·028
Folkestone	10·227	10·213	+·014
Cleethorpe	10·356	10·369	—·013
Lowestoft	10·303	10·278	+·025
Cawston	10·292	10·305	—·013
Cromer	10·291	10·311	—·020

The "probable error" at a single station is $\pm\cdot 014$.

In the map of the isodynamic lines accompanying this survey, the line of 10·332 (in absolute measure, British units) is distinguished by a strong unbroken line passing through the central station in lat. 52° 13′ and long. 1° 38′ W.; the lines of 10·200, 10·300, 10·400, 10·500, and 10·600 being represented by fainter but also unbroken lines. All are computed by the formula

$$\phi=10\cdot 332+\cdot 000557\,a+\cdot 000878\,b,$$

for the intersections of the isodynamic lines with the meridians of 2° E., 1° E., 0°, 1° W., 2° W., 3° W., 4° W., 5° W., and 6° W.

We have now to compare with these the lines determined by the previous survey in 1837. The general Table of the results obtained in that survey by the statical method are given in pp. 190, 191, and 192 of the Report of the 8th (Newcastle) Meeting of the British Association in August 1838; it contains 57 determinations of the total force at stations in England, by five observers acting independently of each other, but adopting the same general principle of experiment. The method of determining the value of the force in absolute measure had not then been introduced, and the values of the force at the different stations are expressed in that Table (as was then the custom) relatively to the force in London expressed by 1·0000; each observer taking some spot in the immediate vicinity of London as his base station, and thus rendering the results of all the observers intercomparable. The stations, their latitudes and longitudes, the initial denoting the observer, and the observed intensity of the force, are collected in the following Table (XV.); the initials F., L., P., R., and S. refer respectively to Mr. Robert Were Fox, Dr. Lloyd, Professor Phillips, Sir James Clark Ross, and myself. Adopting the same central position as that of the present survey, viz. 52° 13′ N. and 1° 38′ W., we have the coordinates of distance a and b as shown in Table XV., and combining these data in the customary manner, we obtain 1·0051 as the representative value of the whole series at the central position expressed in terms of its own arbitrary scale. The force in *absolute measure* at the same central position derived from the experiments of the present survey is 10·332 in British units. Omitting for the present the consideration of any secular change which may have taken place in the value of the force in the interval between the two surveys, we are thus furnished with the means of expressing the results of the first survey in terms which bring them in immediate comparison with those of the second survey. The absolute values thus obtained for the several stations of the first survey are placed in column 8 of Table XV., and being combined in the manner described in pp. 99–101 of the British Association Report for 1836, we obtain for the survey of 1837, $x=+\cdot000521$, $y=+\cdot000742$, $u=-54^\circ\ 52'$, and $r=\cdot0009$; and the formula for computing the force in different parts of England corresponding to the observations of the same survey is

$$\phi=10\cdot332+\cdot000521\,a+\cdot000742\,b,$$

a and b being coordinates of the distance from the central position in 1° 38′ W. and 52° 13′ N., expressed in geographical miles. The several values thus computed are placed in column 9, and the differences between the computed and observed values in column 10. From the latter we find the probable error of a determination at a single station $=\pm\cdot012$. (Table XV. see p. 272.)

The direction of the isodynamic lines in England thus found for the epoch of the present survey is from N. 57° 35′·5 E. to S. 57° 35′·5 W. The direction found by the preceding survey was from N. 54° 54′ E. to S. 54° 54′ W.; the central position being the same in both surveys. It appears, therefore, that the isodynamic lines passing across England have increased the angle which they make with the geographical meridian in the interval between the two surveys. The change is similar in character to the change in the direction of the isoclinal lines in the same interval, but somewhat less in amount.

In the survey of 1837, the rate of increase of the magnetic force in each geographical mile towards the N.W., measured in the direction perpendicular to the isodynamic lines, was ·00091; in the survey of 1860 ·00106. Therefore in the interval the increase of the force towards the N.W. had become more rapid, and the isodynamics corresponding to equal increments of force more closely packed. Hence we may infer that in the northern parts of England the secular increase of the force had been greater than in the southern parts.

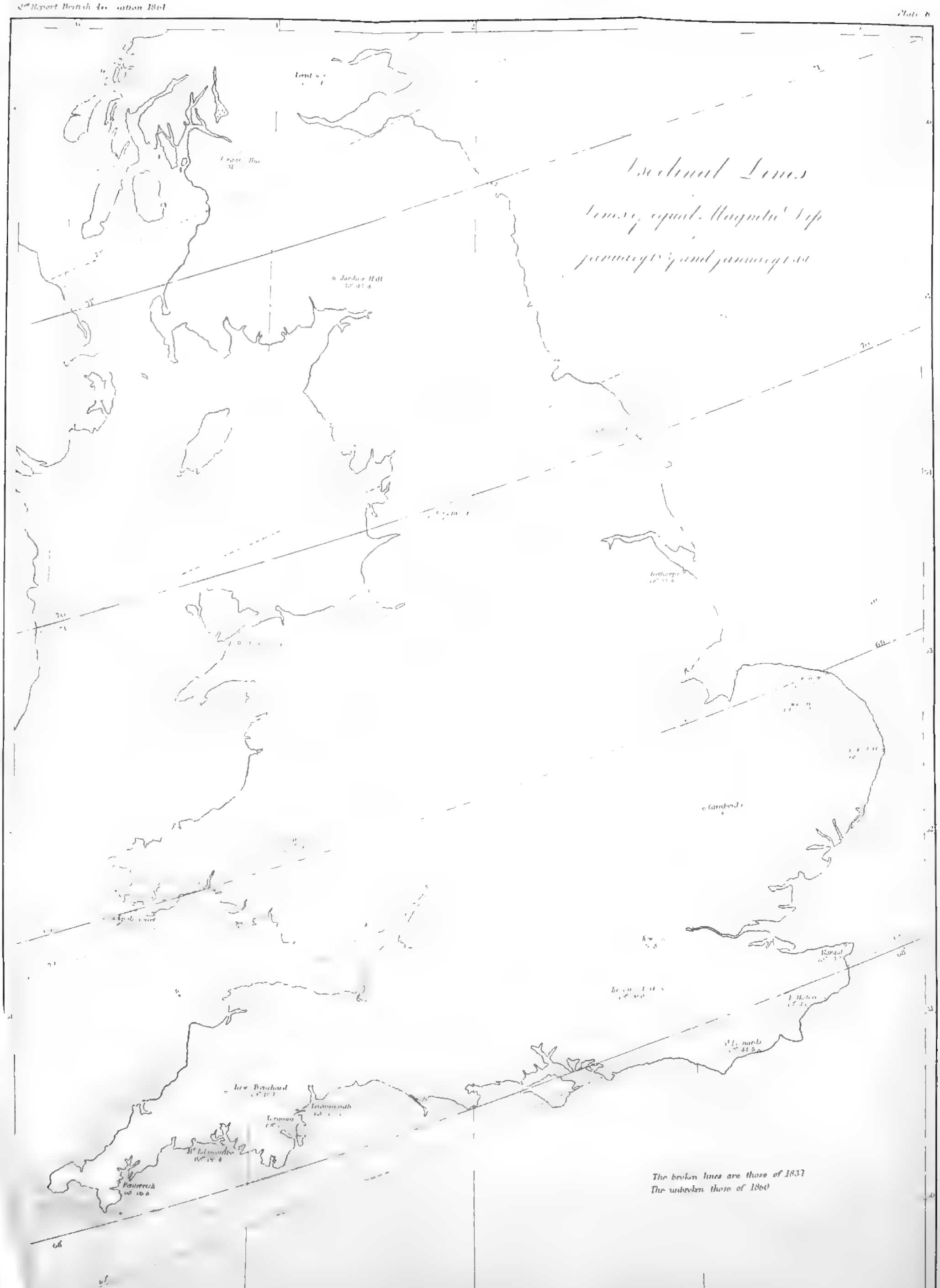
Plate IX. exhibits the fundamental lines of the two surveys in comparison with each other. Both pass through the central position in lat. 52° 13′ N. and long. 1° 38′ W.; that of 1837 at an angle of −54° 54′, and that of 1860 at an angle of 57° 35′·5. Each has the value of 10·332 in British units; which is accurate for 1860, being subject only to errors of observation or of the hypothesis by which the observations are combined; but in 1837 is less certain, because no account is taken of the secular change which may have taken place in the absolute value of the force in the interval between the

TABLE XV.

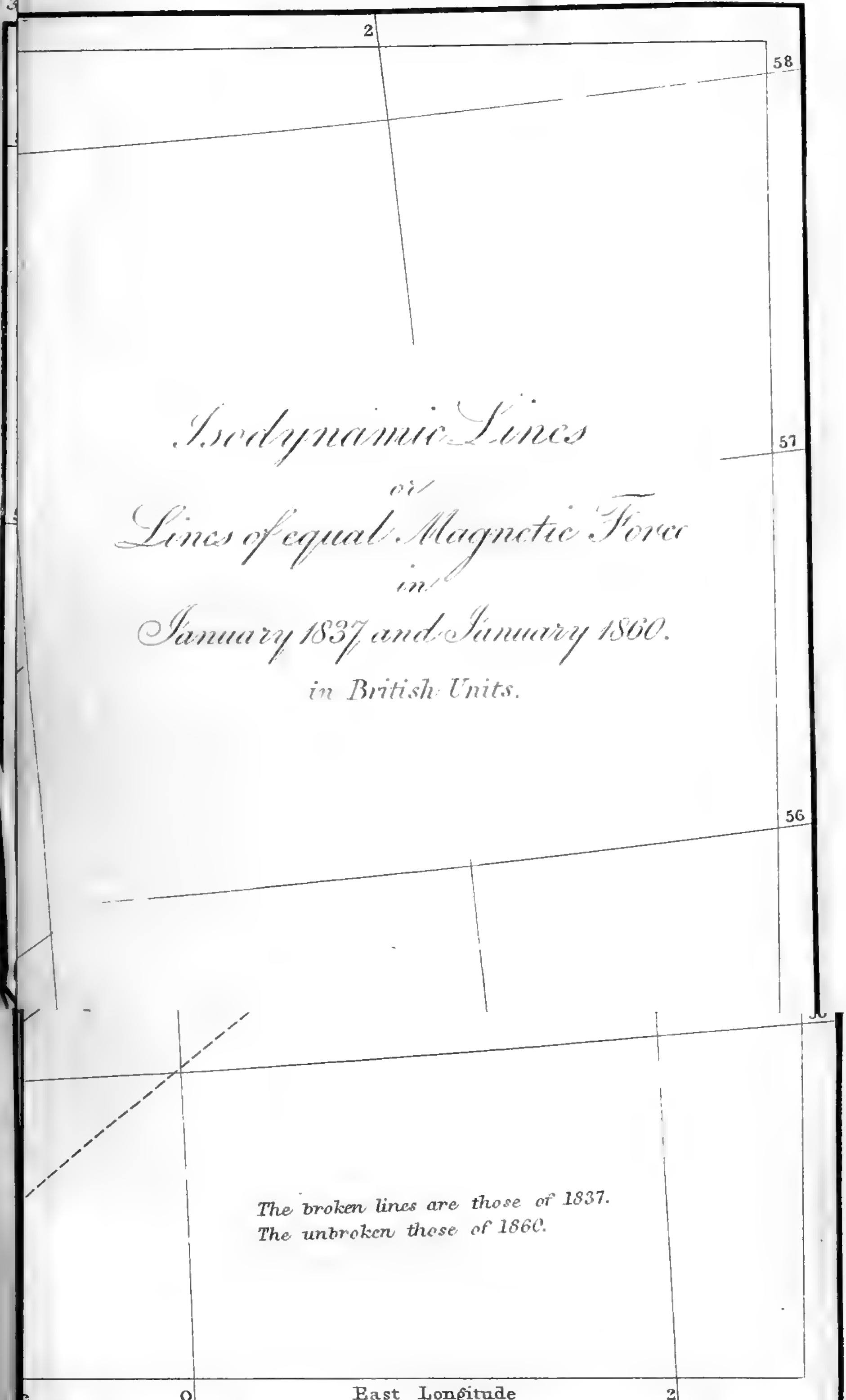
Station.	Long. W.	Lat. N.	Observer.	Intensity. London =1·0000.	Coordinates of distance.		Intensity in British Units.		Difference. Observed —Computed.
					a.	*b.*	Observed.	Computed.	
(1.)	°(2.)ʹ	°(3.)ʹ	(4.)	(5.)	(6.)	(7.)	(8.)	(9.)	(10.)
London	0 07	51 31	.....	1·0000	− 57	− 42	10·280	10·270	+·010
Berwick	2 00	55 45	R.	1·0254	+ 12	+212	10·540	10·495	+·055
Thirsk	1 21	54 14	P.	1·0155	− 10	+121	10·439	10·417	+·022
Newcastle	1 37	54 58	P.	1·0173	− 1	+165	10·457	10·454	+·003
			R.	1·0165	− 1	+165	10·449	10·454	−·005
			S.	1·0147	− 1	+165	10·431	10·454	−·023
Alnwick	1 42	55 25	S.	1·0159	+ 2	+192	10·443	10·475	−·032
Stonehouse	2 44	54 55	R.	1·0173	+ 38	+162	10·457	10·472	−·015
			S.	1·0176	+ 38	+162	10·460	10·472	−·012
Penrith	2 45	54 40	P.	1·0184	+ 38	+147	10·469	10·461	+·008
Carlisle	2 54	54 54	P.	1·0198	+ 44	+161	10·484	10·474	+·010
Bowness	2 55	54 22	P.	1·0182	+ 45	+129	10·467	10·451	+·016
Patterdale	2 56	54 32	P.	1·0181	+ 45	+139	10·466	10·458	+·008
Coniston	3 05	54 22	P.	1·0196	+ 51	+129	10·481	10·454	+·027
Whitehaven	3 33	54 33	S.	1·0176	+ 67	+140	10·460	10·471	−·011
Douglas	4 27	54 10	P.	1·0208	+ 99	+117	10·493	10·470	+·023
Castleton	4 40	54 04	P.	1·0203	+107	+111	10·488	10·470	+·018
Peelton	4 43	54 13	P.	1·0192	+108	+120	10·477	10·477	·000
Flamborough	0 08	54 08	P.	1·0083	− 53	+115	10·365	10·389	−·024
Scarborough	0 24	54 17	P.	1·0103	− 43	+124	10·386	10·402	−·016
Whitby	0 37	54 29	P.	1·0135	− 35	+136	10·418	10·415	+·003
York	1 05	53 58	P.	1·0126	− 19	+105	10·409	10·400	+·009
Doncaster	1 07	53 31	P.	1·0096	− 18	+ 78	10·378	10·381	+·003
Hambleton	1 15	54 20	P.	1·0134	− 13	+127	10·417	10·419	−·002
Osmotherly	1 18	54 22	P.	1·0128	− 12	+129	10·411	10·422	−·011
Sheffield	1 31	53 22	P.	1·0124	− 4	+ 69	10·407	10·381	+·026
Birmingham	1 53	52 28	P.	1·0105	+ 9	+ 15	10·388	10·348	+·040
Shrewsbury	2 45	52 43	L.	1·0077	+ 41	+ 30	10·359	10·375	−·016
			S.	1·0057	+ 41	+ 30	10·338	10·375	−·037
Calderstone	2 53	53 23	P.	1·0106	+ 45	+ 70	10·388	10·407	−·019
Birkenhead	3 00	53 24	L.	1·0112	+ 49	+ 71	10·395	10·410	−·015
			S.	1·0145	+ 49	+ 71	10·428	10·410	+·018
Coed	3 12	53 11	P.	1·0110	+ 56	+ 58	10·393	10·404	−·011
Brecon	3 21	51 57	S.	1·0060	+ 63	− 16	10·341	10·353	−·012
Merthyr	3 21	51 43	S.	1·0081	+ 63	− 30	10·363	10·343	+·020
Dunraven Castle	3 37	51 28	S.	1·0078	+ 74	− 45	10·360	10·337	+·023
Aberystwith	4 05	52 25	S.	1·0100	+ 90	+ 11	10·382	10·387	−·005
Holyhead	4 37	53 19	L.	1·0144	+107	+ 66	10·428	10·437	−·009
Margate	−1 23	51 23	S.	0·9970	−113	− 50	10·249	10·236	+·013
Dover	−1 19	51 08	S.	0·9945	−111	− 65	10·223	10·225	−·002
Lynn	−0 25	52 47	L.	1·0030	− 74	+ 34	10·310	10·317	−·007
Eastbourne	−0 16	50 47	F.	0·9937	− 72	− 86	10·215	10·230	−·015
Cambridge	−0 07	52 13	L.	1·0001	− 64	00	10·281	10·299	−·018
Brighton	0 08	50 50	L.	0·9955	− 57	− 83	10·233	10·242	−·009
Worcester Park	0 17	51 23	S.	1·0006	− 50	− 50	10·286	10·269	+·017
Eastwick Park	0 19	51 17	F.	0·9993	− 49	− 56	10·273	10·264	+·009
Tortington	0 34	50 50	S.	0·9990	− 40	− 83	10·270	10·249	+·021
St. Clairs	1 08	50 44	P.	1·0002	− 19	− 89	10·282	10·256	+·026
Ryde	1 10	50 44	P.	0·9972	− 18	− 89	10·251	10·256	−·005
Salisbury	1 47	51 04	L.	1·0006	+ 6	− 69	10·286	10·284	+·002
Coombe House	2 34	51 31	F.	1·0026	+ 35	− 42	10·306	10·318	−·012
Clifton	2 36	51 27	L.	1·0030	+ 36	− 46	10·310	10·316	−·006
Chepstow	2 41	51 38	L.	1·0041	+ 39	− 35	10·322	10·326	−·004
Hereford	2 44	52 04	L.	1·0046	+ 41	− 9	10·327	10·346	−·019
Lew Trenchard	4 11	50 39	S.	1·0045	+ 96	− 93	10·326	10·314	+·012
Falmouth	5 06	50 09	F.	1·0018	+133	−124	10·298	10·309	−·011
			S.	1·0015	+133	−124	10·295	10·309	−·014

Probable error of a single determination ±·012.

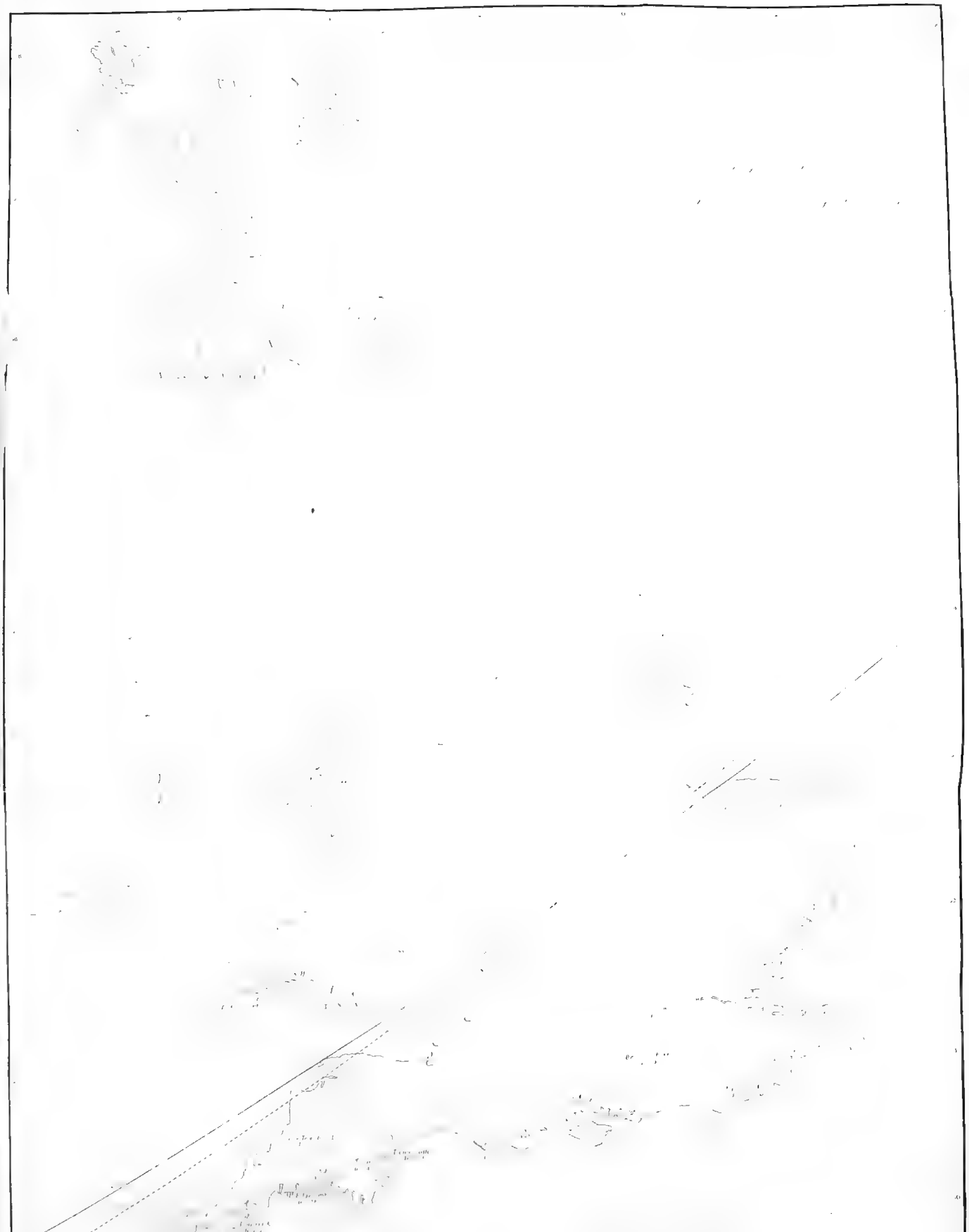

6
0
2
71°
56
50

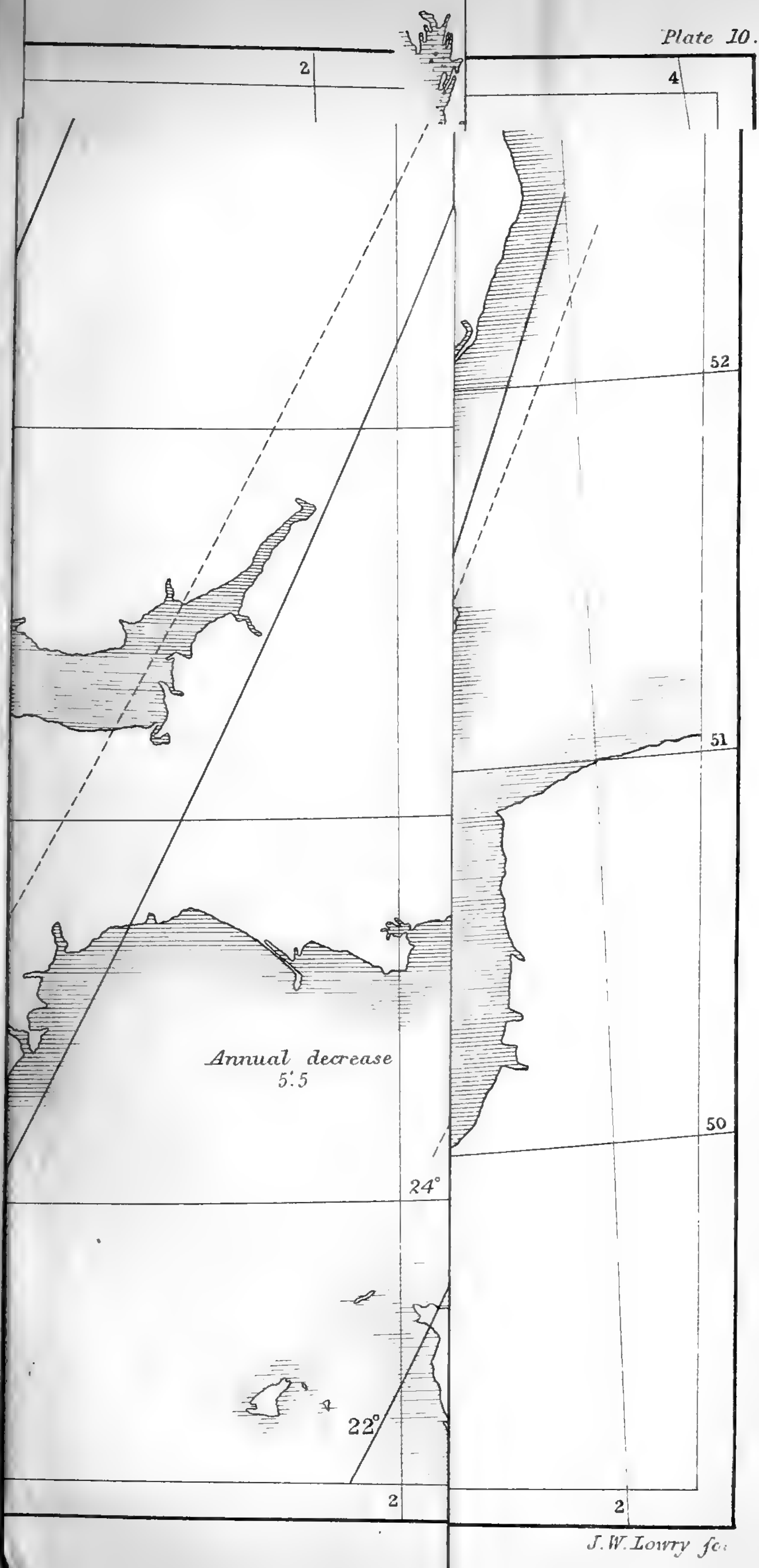


Jardine Hall
The broken lines are those of 1837
The unbroken those of 1860
West Longitude
East Longitude

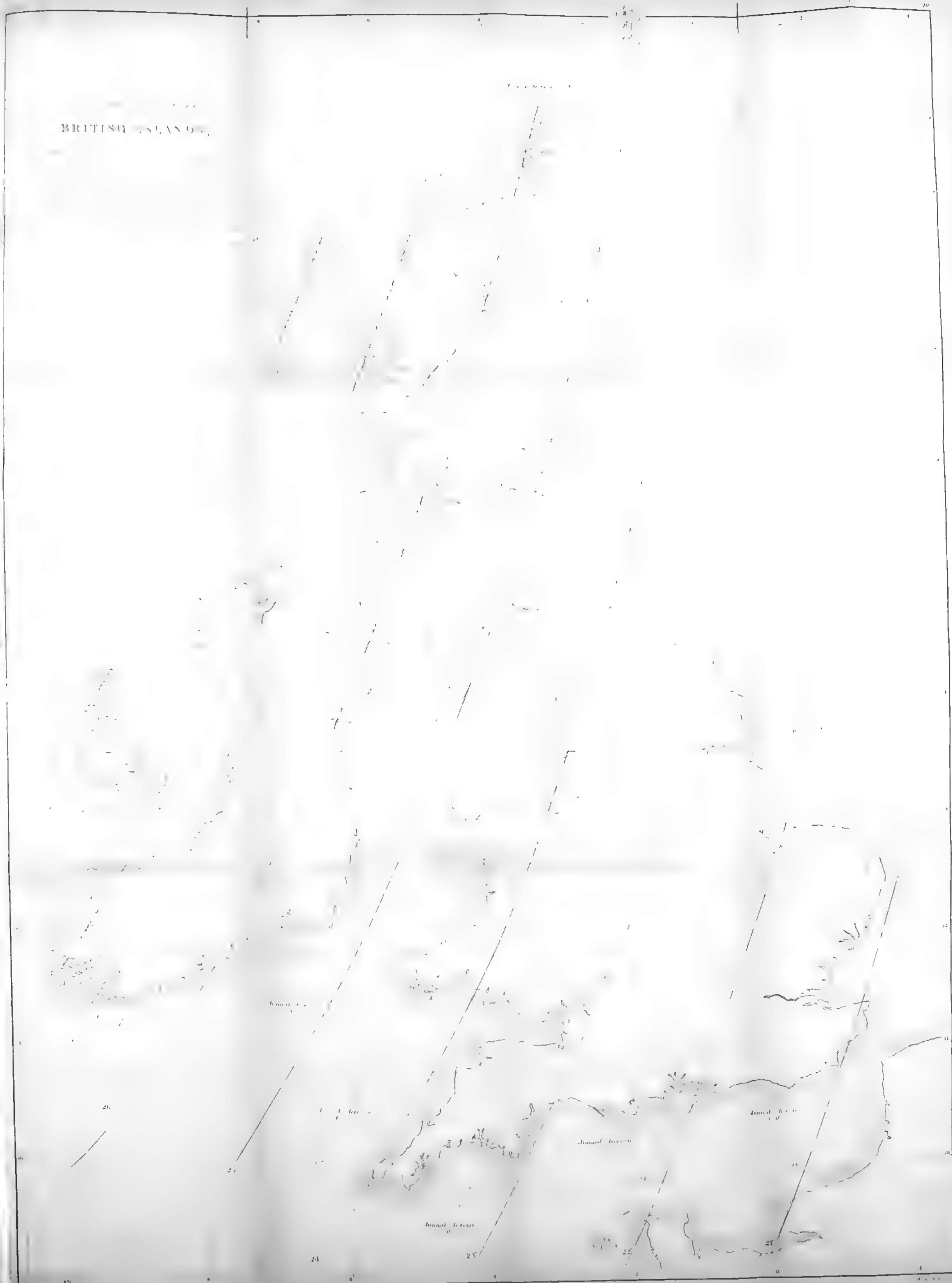

Isodynamic Lines
or
Lines of equal Magnetic Force
in
January 1837 and January 1860.
in British Units.
2
58
57
56
The broken lines are those of 1837.
The unbroken those of 1860.
0
East Longitude
2

J.W. Lowry sc.


West Longitude
East Longitude



J. W. Lowry sc.


BRITISH

two surveys. We have no means of estimating with precision the operation of the secular change in this interval, inasmuch as we have no absolute measures of the force at so early a date as that of the survey in 1837. The only satisfactory determinations which we now possess, from which an approximate value of the secular change for one particular station, and for a part of the interval, may be inferred, are the absolute measures made monthly at the Kew Observatory since April 1857. From these the force appears to have increased between April 1857 and March 1862 at an average rate of ·00125 annually. If we assume the same rate of increase to have taken place in the same years at the central position, which is not far distant from Kew, and if we extend the assumption so as to include the whole interval between the two surveys, the value of the fundamental line of the survey of 1837 would be 10·303 instead of 10·332; and the isodynamics for 10·200, 10·300, 10·400, 10·500, and 10·600 for 1837 in Plate ii., computed by the formula

$$10{\cdot}332 + {\cdot}00052\,a + {\cdot}00074\,b$$

(a and b being the distances in longitude and latitude in geographical miles from the central position), and represented in the Plate by broken lines, would each require to be diminished by 0·029. It is obvious, however, from the increase in the value of r (viz. ·00091 in the earlier survey, and ·00106 in the later), that the secular increase of the force must have been greater in the northern parts of England than at Kew, or generally those in the southern parts of the kingdom. We must recognize also the operation of the increase in the value of u from $54^\circ\ 54'$ to $57^\circ\ 35'{\cdot}5$ in producing a small diminution in western longitudes of the secular increase observed at Kew, and which has been inferred to have been still greater in the northern and eastern parts. It is to be hoped that the series of monthly determinations at Kew, which appear to give a satisfactory approximate measure of the secular change of this element during the last five years, may be continued until the survey be repeated at the expiration of a third interval; and that in the mean time determinations similar to those at Kew, and equally satisfactory, may be made in other parts of the British Islands; the present conclusions regarding the secular change of the force in the interval between 1837 and 1860 must be necessarily imperfect.

Division III.—*Declination.*

[Contributed by Frederick John Evans, Esq., R.N., F.R.S., Superintendent of the Compass Department of the Royal Navy.]

Plate X. exhibits a comparative view of the isogonic lines, or lines of equal magnetic declination, corresponding to the epochs 1837 and 1857. The lines corresponding to the first of these epochs have been drawn in conformity with a map of the isogonic lines crossing the British Islands in 1840, published in plate 23 of 'Johnston's Physical Atlas' (2nd edition), contributed to that work by Major-General Sabine. The authorities on which the lines for 1840 were drawn may be found in a memoir in the Philosophical Transactions for 1849, art. xii. The small corrections required to reduce these lines to the epoch of 1837 have been made.

The isogonics corresponding to the later epoch (1857) rest on the authority of the observations contained in the subjoined Table (No. XVI.). The instruments chiefly used were either the Admiralty Standard Compass, or Kater's Azimuth Compass; all of which had undergone previous examination and adjustment at the Compass Observatory at Woolwich.

TABLE XVI.—Magnetic Declinations.

Station.	Lat.	Long.	Date.
	° ′	° ′	
Bridlington	54 5 N.	0 12 W.	1856. Sept. 2
Bridlington	54 5	0 12	1856. Sept. 3
Grimsby	53 34	0 5	1856. Sept. 4
Woolwich, Compass Observatory	51 29	0 2 E.	1857. Jan. 1 ...
Shoreham	50 51	0 15 W.	1857. July 8 ...
Start Point	50 13	3 39	1858. Sept. 24*... 1859. Aug. 18*...
Salcombe, near the Bar	50 13	3 47	1857. Aug. 20 ... 1858. Sept. 20*...
Bolt Head	50 13	3 50	1859. Aug. 19*...
Bolt Tail	50 14	3 52	1857. Aug. 18 ... 1858. Sept. 14*...
Bigbury	50 17	3 53	1857. Aug. 14 ... 1858. Sept. 13*...
Wennel Hill, Bigbury Bay	50 18	3 56	1857. Aug. 14 ... 1858. Sept. 13*...
Plymouth, Stoke	50 23	4 10	1856. June 6 ... 1857. July 5 ...
„ Stonehouse	50 22	4 8	1856. April 22 ...
„ Staddon	50 20	4 7	„ Sept. 1 ... 1857. May 22 ... 1858. Sept. 27*... 1859. Oct. 26*...
„ Maker	50 20	4 12	1857. July 3 ... „ Sept. 15 ... „ Sept. 16 ...
Deadman	50 13	4 48	1856. Jan. 3 ... „ Jan. 7 ...
Falmouth, St. Just	50 11	5 1	„ Jan. 1 ...
Cornwall, St. Agnes Beacon	50 18	5 13	1858. Nov. 9*...
„ Mounts Bay	50 10	5 31	1860. Dec. 5*...
Scilly Islands, St. Martin's Head	49 58	6 16	1859. Aug. 4*...
„ Brehar Island	49 57	6 21	1861. Aug. 16*..
Tenby, St. Catherine Island	51 40	4 43	1856. Oct. 23 ...
Liverpool	53 25	3 1	„ Jan. 7 ... „ Jan. 3 ...
Jersey, St. Helier's	49 12	2 5	1857. July 13 ...

* Observations not employed in

Coasts of England.

Greenwich Mean Time of Observation.	Declination. Observed.	Declination. Reduced to January 1, 1857.		Observer.
h m	° ′	° ′		
2 44 P.M.	22 36 W.	22 34	W.	
3 14 P.M.	22 31	22 29		
3 17 P.M.	22 41	22 39		
4 37 P.M.	23 2	22 59		
4 40 P.M.	22 58	22 55	° ′ 22 43·6	
4 43 P.M.	22 47	22 44		
9 54 A.M.	22 56	22 51		
9 56 A.M.	22 48	22 42		
1 25 A.M.	22 48	22 39		Rear-Admiral Sir J. C. Ross.
12 7 P.M.	22 31	22 20		
12 10 P.M.	22 34	22 23		
12 58 P.M.	22 49	22 42		
3 51 P.M.	22 37	22 31		
4 6 P.M.	22 32	22 26	22 29·5	
4 22 P.M.	22 36	22 31		
4 31 P.M.	22 34	22 29		
4 40 P.M.	22 36	22 31		
5 0 P.M.	22 37	22 32		
......	......	......	21 46	Mr. Evans, R.N.
6 10 P.M.	21 54	......	22 2	
11 15 A.M.	22 43	22 51	22 47	
9 50 A.M.	22 31	22 43		
5 33 P.M.	23 12	23 20	23 15·5	
11 15 A.M.	23 6	23 11		
2 35 P.M.	23 9	......	23 21	
8 15 A.M.	23 19	23 25	23 21	Commander H. L. Cox, R.N.
8 15 A.M.	22 59	23 17		
4 15 P.M.	23 20	23 28	23 27	
5 45 P.M.	23 12	23 26		
8 45 A.M.	23 10	23 14	23 12·5	
2 35 P.M.	23 5	23 11		
3 15 P.M.	23 31	23 22	23 24	Commander E. Burstall, R.N.
4 16 P.M.	23 25	23 26		Commander H. L. Cox, R.N.
9 45 A.M.	23 17	......	23 19	
11 15 A.M.	23 28	23 20		
3 15 P.M.	23 33	23 28	23 29·7	Commander H. L. Cox, R.N.
5 36 P.M.	23 23	23 37		
10 45 A.M.	23 15	23 34		
3 16 P.M.	23 10	23 18		
3 37 P.M.	23 8	23 10	23 19·7	
1 17 P.M.	23 27	23 31		
1 17 P.M.	23 50	23 48	23 46	
1 17 P.M.	23 51	23 44		
1 17 P.M.	24 6	......	24 1	Captain G. Williams, R.N.
1 0 P.M.	23 38	......	23 44	
1 0 P.M.	23 15	......	23 41	
1 0 P.M.	23 50	......	24 3	
1 0 P.M.	23 46	......	24 13	
1 0 P.M.	24 30	......	24 26	Commander Alldridge, R.N.
0 42 P.M.	24 0	23 54	23 55·5	Mr. W. W. Rundell.
3 12 P.M.	24 1	23 57		
7 10 A.M.	21 35	......	21 44	Mr. Evans, R.N.

the construction of the Chart.

TABLE XVII.—Magnetic Declinations.

Station.	Lat.	Long.	Date.
	N.	W.	
	° ′	° ′	
Lough Swilly, Binnion Bay	55 17	7 27	1855. Aug. 17. ...
Rathmullan, Hill Head	55 5	7 32	„ Dec. 17 ...
„ „	„	„	1856. Jan. 2 ......
„ „	„	„	„ Jan. 5 ......
„ „	„	„	„ „
Mulroy Bay, Daulty Island	55 13	7 47	„ Oct. 13......
Tralee, Canal Basin	52 16	9 43	„ Nov. 5 ......
„ „	„	„	„ Nov. 7 ......
„ „	„	„	„ Nov. 15 ...
„ Blennerville Church	52 15	9 44	„ Nov. 1 ......
„ „	„	„	„ Nov. 6......
„ „	„	„	„ Nov. 17 ...
„ Large Samphire Island	52 16	9 52	„ Oct. 31 ...
„ „	„	„	„ Nov. 14 ...
„ Samphire Island Lighthouse	52 16	9 53	„ Oct. 22 ...
„ „	„	„	„ Nov. 14 ...
Kenmare, Cleanderry	51 44	9 56	„ Jan. 9 ......
„ „	„	„	„ Jan. 10 ...
„ „	„	„	„ „
Bearhaven, Dinish Island	51 39	9 51	„ Jan. 1 ......
„ „	„	„	„ Jan. 5 ......
„ „	„	„	„ „
„ „	„	„	„ Jan. 1 ......
„ „	„	„	„ Jan. 5 ......
„ „	„	„	„ Jan. 3 ......
Dingle	52 8	10 17	1860. Aug. 15* ...
Smerwick	52 11	10 25	„ Aug. 24* ...
Valentia	51 55	10 18	„ Sept. 4* ...
Crookhaven	51 28	9 42	„ Sept. 29*...
Castlehaven	51 30	9 11	„ Sept. 6* ...
Larne, the Curran	54 52	5 50	1856. July 28 ...
„ „	„	„	„ Sept. 10 ...
„ „	„	„	„ Sept. 26 ...
Dundalk	54 1	6 24	1858. May 14* ...
„	53 52	6 15	„ July 23* ...
Strangford	54 20	5 33	„ Aug. 16* ...
Dublin, Magnetic Observatory	53 21	6 16	1857. Jan. 30 ...

* Observations not employed in

Coasts of Ireland.

Greenwich Mean Time of Observation.	Declination. Observed.	Declination. Reduced to January 1, 1857.		Observer.
	West.	West.		
h m	° ′	° ′	° ′	
....	27 1	......	26 54	
2 30 P.M.	27 19	27 9		
2 45 P.M.	27 22	27 13	27 12·5	Captain G. A. Bedford, R.N.
2 0 P.M.	27 18	27 11		
3 0 P.M.	27 23	27 17		
4 2 P.M.	27 19	......	27 14	
1 38 P.M.	27 36	27 31		
3 40 P.M.	27 27	27 25	27 29	
1 38 P.M.	27 32	27 31		
0 10 P.M.	27 29	27 26		
2 40 P.M.	27 21	27 19	27 21·3	Commanders R. Beechey and A. G. Edye, R.N.
0 40 P.M.	27 22	27 19		
4 40 P.M.	27 32	27 29	27 27	
4 40 P.M.	27 28	27 25		
0 40 P.M.	27 27	27 23	27 29	
2 55 P.M.	27 37	27 35		
1 15 P.M.	26 38	26 31		
1 10 P.M.	26 45	26 40	26 38	
2 10 P.M.	26 47	26 43		
3 0 P.M.	26 56	26 50		
2 10 P.M.	26 54	26 47		Commander W. H. Church, R.N.
3 25 P.M.	27 03	26 58	26 42·5	
3 40 P.M.	26 35	26 30		
2 40 P.M.	26 42	26 36		
3 10 P.M.	26 39	26 34		
0 8 P.M.	27 27	......	27 44	
3 37 P.M.	27 19	......	27 41	
4 3 P.M.	27 15	......	27 39	Commander A. G. Edye, R.N.
11 8 A.M.	26 36	......	27 2	
10 30 A.M.	26 27	......	26 53	
2 23 P.M.	25 54	25 43		
11 23 A.M.	26 8	25 57	25 54·7	
10 23 A.M.	25 42	26 4		Mr. R. Hoskyn, R.N.
....	26 29	......	26 34	
....	26 25	......	26 30	
....	25 48	......	25 53	
10 25 A.M.	25 40	......	25 45	Rev. J. Galbraith, M.A.

the construction of the Chart.

Table XVIII.—Magnetic Declinations.

Station.	Lat.	Long.	Date.
	N.	W.	
	° ′	° ′	
Thurso	58 36	3 31	1856. June 25 ...
Loch Eribol, Hoan Island	58 34	4 40	„ June 27 ...
„ „	„	„	„ June 28 ...
Hebrides, Carloway	58 17	6 47	„ Aug. 11 ...
„ „	„	„	„ Aug. 26 ...
Kyle Akin	57 16	5 44	„ Aug. 2 ...
Hebrides, North Uist, Loch Maddy	57 36	7 8	1858. Nov. *...
Hebrides, Monach Islands, Shillay	57 31	7 42	1859. Aug. *...
Hebrides, North Uist, Loch Eport	57 32	7 11	„ Oct. 6*...
Barra Sound, Friday Island	57 3	7 23	1861. Oct. 15* ..
Little Loch Shell	58 1	6 26	1856. Sept. 18 ...
„	„	„	„ Sept. 19 ...
Oban, Dunolly Hill	56 25	5 27	„ Jan. 1 ...
„ „	„	„	„ Jan. 2 ...
„ „	„	„	„ Jan. 3 ...
„ „	„	„	„ Jan. 4 ...
„ „	„	„	„ Jan. 7 ...
„ „	„	„	„ Jan. 8 ...
„ „	„	„	„ Jan. 11 ...
„ Kerrera Island	56 25	5 30	„ Jan. 9 ...
Firth of Forth, near Dunbar	56 0	2 32	1855. Oct. 24 ...
„ Broxburn	„	2 29	1856. June 23 ...
„ Cove	55 57	2 21	„ Aug. 23 ...
„ Redheugh	55 55	2 16	„ „ ..
„ Fast Castle	„	2 14	„ „ ...
St. Abbs	„	2 8	„ Sept. 16 ...
„ Coldingham shore	55 54	2 8	„ „ ...

* Observations not employed in

Table XIX.—Magnetic Declinations observed at Sea

North Sea	55 41	6 28E.	1856. Apr. 16 ...
„	55 27	6 7	„ „ ...
„	54 30	5 10	„ „ ...
„	54 27	5 4	„ „ ...
„	52 33	3 13	„ „ ...
„	55 6	0 0	„ June 20 ...
„	57 22	1 44 W.	„ June 23 ...
Atlantic Ocean	58 37	6 26 W.	„ Aug. 7 ...
„	58 25	6 46	„ Aug. 9 ..

Coasts of Scotland.

Greenwich Mean Time of Observation.	Declination. Observed.	Declination. Reduced to January 1, 1857.		Observer.
	West.	West.		
h m	° ′	° ′	° ′	
11 15 A.M.	26 8	......	26 1	Captain H. C. Otter, R.N. Observations made with Adie's Variation Needle.
2 48 P.M.	27 18	27 7	27 11·5	
6 45 P.M.	27 16	27 16		
4 27 P.M.	28 7	27 59	27 57	
11 27 P.M.	28 3	27 55		
4 52 P.M.	27 29	......	27 26	
3 30 P.M.	27 38	......	27 46	
5 0 P.M.	27 15	......	27 33	
3 15 P.M.	28 16	......	28 31	
0 30 P.M.	27 27	......	27 50	
2 0 P.M.	27 24	27 17	27 18	
9 45 P.M.	27 20	27 19		
2 22 P.M.	27 3	27 3	27 0·6	Commander E. Bedford, R.N.
2 22 P.M.	27 5	27 5		
1 55 P.M.	27 2	27 0		
1 55 P.M.	27 3	26 56		
1 50 P.M.	27 4	26 57		
2 20 P.M.	27 6	27 2		
2 10 P.M.	27 6	27 1		
2 22 P.M.	26 45	......	26 39	
11 10 A.M.	24 56	24 50	24 40	Lieut. F. Thomas, R.N. Observations made with Adie's Variation Needle.
11 10 A.M.	24 36	24 30		
11 10 A.M.	24 40	......	24 31	
2 10 P.M.	24 37	24 22	24 22	
4 10 P.M.	24 29	24 22		
0 10 P.M.	24 28	24 20	24 20	
10 10 A.M.	24 23	24 20		

the construction of the Chart.

off Coasts of United Kingdom.

4 5 A.M.	19 44	......	19 41	Captain H. C. Otter, R.N., in H.M.S. 'Porcupine.' Note.—The ship's head in each case was placed on the point of no deviation, and the engines eased.
6 25 A.M.	19 58	......	19 56	
5 0 P.M.	20 5	......	20 2	
5 40 P.M.	19 52	......	19 50	
6 0 P.M.	20 37	......	20 34	
7 30 A.M.	23 26	......	23 26	
3 10 P.M.	25 10	......	25 2	
7 45 P.M.	28 17	......	28 18	
7 25 A.M.	28 16	......	28 13	

Interim Report of the Committee for Dredging on the North and East Coasts of Scotland.

At the Aberdeen Meeting of the British Association, a Committee was appointed for the purpose of carrying on a system of dredging on the North-eastern Coast of Scotland, consisting of Dr. Ogilvie, Dr. Dickie, Professor Nicol, Dr. Dyce, and Mr. Peach; and £25 was granted for that purpose. Of this sum £5 was allotted to Mr. Peach, to enable him to conduct investigations at Wick.

In 1860 the few weeks available for dredging, before the meeting of the Association in July, were so tempestuous and generally unfavourable, that no part of the grant was expended; but in the course of the autumn, a trial was made off the coast of Banffshire. During the past summer, 1861, several dredging expeditions were planned and completed off the Bay of Aberdeen and adjacent coasts, none exceeding a distance of twelve miles from land.

The Committee in Aberdeen considered it advisable to receive the aid of others besides Mr. Peach, and to have trials made at points intermediate between Aberdeen and Wick, in order to render the investigations as complete as possible; and with this view the assistance of the Rev. W. Grigor, of Macduff, was asked, and readily accorded, a part of the grant being allotted to him. They have also secured the cooperation of another zealous naturalist, Mr. Dawson, of Cruden. This gentleman has just put at their disposal a valuable and interesting report on the Mollusca of Cruden Bay; but the others have not yet had sufficient time to allow of any report; and at Aberdeen, the examination of the materials collected being still in progress, the Committee are under the necessity of reserving the details for a further report. The general results, however, have been such as to lead them to hope that the sum of £25 will be granted for one year more, in order that the dredging may be further carried on, and at greater depths and distances from land.

No regular dredging has previously been conducted on this part of the Scottish coast; but the Committee have now the satisfaction of observing that, owing mainly to the admission of parties of students of the University to the dredging excursions, a feeling of interest has been awakened in the pursuit, from which the best results may be anticipated, and there can be no doubt that several ardent young men have thus been thoroughly trained in carrying on such operations in the open sea.

The Committee would urge these as reasons for a renewal of the grant, that they may be thus enabled to procure materials for a complete report at the meeting of the Association in 1862.

George Ogilvie, *for the Committee.*

August 31, 1861.

On the Resistance of Iron Plates to Statical Pressure and the Force of Impact by Projectiles at High Velocities. By William Fairbairn, Esq., *LL.D., F.R.S., &c., President of the Association.*

The discovery of the application of iron plates as a means of defence against ordnance of great power and force are of recent date, and are attributable to His present Majesty the Emperor of the French. Since 1858 numerous experiments have been made to test the quality of the iron, and to determine the thickness of the plates employed for that purpose; but it is only of late years that the value and importance of this description of defence has been ascertained as a covering for the sides of ships of war. The very powerful resistance of iron to projectiles at high velocities has directed most of the maritime powers of Europe to the advantage of armour-plating ships for the purpose of protecting them from the destructive effects of shot; and it has now been proved that a sheathing of plates 4½ inches thick, covering the sides of a ship, extending to a depth of six feet below the water-line, is a sufficient protection against existing guns of the heaviest calibre. It is true that more powerful ordnance may be successfully tried against plates from 5 to 5½ inches thick, but they are too heavy for general use on board ship; and as vessels of the present tonnage are not calculated to carry plates of greater thickness than 4½ or 5 inches, it is more than probable that the country must be content with such protection as plates of these dimensions can afford.

Much, however, depends on the quality of the material of which they are composed; and the object of this communication is to furnish not only data for the manufacture of them, but to point out their mechanical properties and the best mode of attaching them to the ship.

There are two descriptions of vessels to which armour-plates may be applied, namely, those of iron, and the present existing vessels, composed entirely of wood. In the present state of our knowledge, it is desirable that all vessels of war should be formed of iron; but the transfer is a work of time, and the question now for consideration is, how to make our present wooden ships invulnerable, and how to apply the material to effect a maximum power of resistance to shot. This is the great question for solution, and the Admiralty, fully alive to the importance of the change, has instituted a long and laborious series of experiments to determine these results.

It is well known that all substances of a brittle nature are easily broken by impact, and the best kind for resisting blows is a tenacious, tough, and ductile material. To secure all these properties is a desideratum in the manufacture of iron plates, and one which never ought to be neglected. In submitting the following results obtained from the experiments, it may be interesting to show the chemical compositions of some of the best irons experimented upon, and those marked with the letters A, B, C, and D, when carefully analysed, were found to contain the following ingredients:—

Mark.	Carbon.	Sulphur.	Phosphorus.	Silicon.	Manganese.
A.	0·01636	0·104	0·106	0·122	0·28
B.	0·03272	0·121	0·173	0·160	0·029
C.	0·023	0·190	0·020	0·014	0·110
D.	0·0436	0·118	0·228	0·174	0·250
E.	0·170	0·0577	0·0894	0·110	0·330

Comparing the chemical analysis with the mechanical properties of the irons experimented upon, we find that the presence of ·023 per cent. of carbon causes brittleness in the iron; and this was found to be the case in the homogeneous iron plates marked C*; and although it was found equal to A plates in its resistance to tension and compression, it was very inferior to the others in resisting concussion or the force of impact. It therefore follows, that toughness combined with tenacity is the description of iron plate best adapted to resist shot at high velocities. It is also found that wrought iron, which exhibits a fibrous fracture when broken by bending, presents a widely

* Homogeneous iron is that description of iron or steel which is not rolled or manufactured from piled bars, but obtained by the boiling process from the furnace, where the amalgamation is complete; or, in other words, it is obtained from cast ingots according to the Bessemer process, or direct from the bloom as it leaves the puddling furnace.

different aspect when suddenly snapped asunder by vibration or a sharp blow from a shot. In the former case the fibre is elongated by bending, and becomes developed in the shape of threads as fine as silk, whilst in the latter the fibres are broken short and exhibit a decidedly crystalline fracture. But, in fact, every description of iron is crystalline in the first instance; and these crystals, by every succeeding process of hammering, rolling, &c., become elongated, and resolve themselves into fibres. There is, therefore, a wide difference in the appearance of the fracture of iron when broken by tearing and bending, and when broken by impact, where time is not an element in the force producing rupture.

The mechanical properties of iron best calculated to resist the penetration of shot at high velocities are enumerated as follows.

The plates were subjected to statical tensile strain, to compression, and to punching, with the following results.

1. *Specific Gravity.*

The mean specific gravity of the $1\frac{1}{2}$, 2, $2\frac{1}{2}$, and 3-inch plates of each series were as follows:—

A plates	7·8083
B plates	7·7035
C plates	7·9042
D plates	7·6322

The order of merit is therefore C, A, B, D. These results coincide with the following tests.

2. *Tensile Strength.*

The statical resistance to tensile strain was as follows:—

	Tensile strain per square inch in tons.	
	Thinner plates.	Thicker plates.
A plates	25·047	24·644
B plates	25·606	23·354
C plates	31·770	27·032
D plates	18·333	24·171

The general order of merit in this case is C, A, B, D. The homogeneous metal plates have the highest tenacity, but decrease in strength progressively as the plates increase in thickness.

3. *Ductility of the Plates.*

A measure of the ductility of the plates is afforded by the ultimate elongation under tensile strain.

	Ultimate elongation per unit of length.	
	Thinner plates.	Thicker plates.
A plates	·0690	·2723
B plates	·0566	·2459
C plates	·1880	·2725
D plates	·0197	·1913

Here the order of merit is nearly the same as that for density and tenacity. On the whole the elongations increase progressively with the thickness for iron plates, and decrease for homogeneous metal plates. But with iron the ductility is nearly the same for 2, $2\frac{1}{2}$, and 3-inch plates.

4. *Resistance to Impact.*

Mr. Mallet has pointed out that the product of the tensile breaking weight and the ultimate elongation of iron indicates its resistance; or, in other words, the product of the tenacity and ductility of iron affords a measure of the dynamic resistance of the material, or its resistance to impact. The following numbers give this coefficient of rupture:—

	Mallet's coefficient in foot pounds. Thinner plates.	Thicker plates.
A plates	1941	7544
B plates	1716	6476
C plates	6593	8265
D plates	493	5115

To ascertain this coefficient with accuracy, rather longer specimens should have been tested; but, bearing in mind this source of inaccuracy, the numbers strikingly correspond with the results obtained by impact. It is not of much use to compare directly the resistances obtained with those given above, because the former were made with such large intervals (half-inch) in the thickness of the plates that they afford no criterion of the relative values of the different descriptions of iron. But we may compare the iron and steel plates, where the difference of resistance, being greater, is to some extent indicated in the experiments with ordnance.

Thickness of plates.	Dynamic resistance. Iron plates.	Steel plates.
Half inch	1·00	1·72
One and a half inch	1·00	1·19
Two inches	1·00	1·20
Two and a half inches	1·00	1·17
Three inches	1·00	0·88

With these results obtained by simple pressure, we compare those obtained by ordnance. The resistance of the iron plates being again taken as unity, the resistance of the steel plates was as follows:—

Weight of projectile.	Mean thickness of plates.	Dynamic resistance. Iron.	Steel.
0·344	·75	1·00	1·97
6·25	1·20	1·00	1·18
11·56	1·75	1·00	1·00
24·81	2·38	1·00	0·81

From the above it will be seen that there is quite as close an approximation in the ratios in these two tables, for corresponding thicknesses of plate, as could be expected from the nature of the experiments. Both the series of experiments (viz., that with dead pressure and that with ordnance) indicate the same increasing resistance of the iron plates, and decreasing resistance of the steel plates; and the ratios of their relative resistances are nearly the same. In making the comparison, the resistance to ordnance is assumed to be as the square of the thickness of the plates—a law which will hereafter be demonstrated.

The relative values of the plates in resisting shot are, according to the experiments with dead pressure, as follows:—

A plates	1000
B plates	858
C plates	1095
D plates	688

These numbers are deduced from the results on the $1\frac{1}{2}$, 2, $2\frac{1}{2}$, and 3-inch plates. With 3-inch plates the iron is much stronger than the steel.

5. *Resistance to Compression.*

The results on compression have no direct bearing on the resistance to projectiles; it is not therefore necessary to give an abstract.

6. *Statical Resistance to Punching.*

These experiments were arranged in three series with a view to determine the resistance to punching with different sizes of shot, with different thicknesses of plate, and with flat- and round-faced punches.

First Series of Experiments.

In this series the punch was flat-faced, and in all respects similar to the projectile of the wall-piece employed at Shoeburyness. The resistance of the plates was as follows:—

Thickness of Plates in inches.	Mark of Plates.	Statical Resistance to punching in lbs.
0·25	A	29,604
	B	19,428
	C	31,604
	D	18,980
0·50	A	57,956
	B	57,060
	C	71,035
	D	49,080
0·75	B	84,587
	D	82,381

The shearing strain varied from 13 to 20 tons per square inch in the case of iron, and from 21 and 23 tons with homogeneous metal.

Second Series of Experiments.

Punch flat-faced, and half an inch in diameter. Hole in die-block beneath $1\frac{1}{2}$ inch diameter. The resistances to punching were as the following numbers:—

Thickness of Plates in inches.	Mark of Plates.	Statical Resistance to punching in lbs.
0·50	A	33,980
	B	31,972
	C	48,100
	D	31,345
0·75	B	46,996
	C	48,788
	D	48,146
1·00	B	62,584
	D	60,696

In this case the shearing stress per square inch of section varied from 17 to $19\frac{1}{4}$ tons in the case of iron, and from $18\frac{1}{2}$ to 27 tons in the homogeneous metal.

In both these series the plates stand in the same order of merit, which is also identical with that in which they were placed as regards tenacity and density, viz., C, A, B, D. Their relative value is as follows:—

A plates	1·000
B plates	0·907
C plates	1·168
D plates	0·873

Third Series of Experiments.

In this series a punch of the same diameter as the bullet of the wall-piece was employed, but it was round-faced, like the cast-iron service shot. The same die was employed, the object being to determine the difference of penetrating power of round- and flat-faced projectiles. In the following table the resistances are given, and those of the flat-faced punch of the first series are placed beside them, for comparison.

		Statical Resistance to punching in lbs. Flat-faced punch.	Statical Resistance to punching in lbs. Round-faced punch.
Half-inch plates.	A plates	57,956	61,886
	B plates	57,060	48,788
	C plates	71,035	85,524
	D plates	49,080	43,337
Three-quarter-inch plates.	B plates	84,587	98,420
	D plates	82,381	98,571
	Means	67,017	72,754

These figures show that the *statical* pressure required to punch plates of the same thickness is about the same, whether the punch be round- or flat-faced.

It is further shown in a detailed manner that, for the same pressure, the volume displaced by indentation is the same for flat- and round-faced punches.

Thence it follows that, where the plate does not exceed in thickness the diameter of the punch, the depth of indentation is much greater with round- than with flat-faced punches.

And lastly, since the dynamic resistance which corresponds with the resistance to projectiles, varies as the product of the statical pressure and the depth of indentation, it thence follows that the dynamic resistance to round-faced projectiles is much greater than the resistance to flat-faced projectiles.

The general laws indicated in these experiments are as follows:—

1. *Size of shot or punch.*—The resistance varies directly as the circumference of the shot.

2. *Statical resistance of plates of different thickness.*—With plates of different thickness the statical resistance varies directly as the thickness. If the thicknesses be as 1, 2, 3, &c., the resistances will be as 1, 2, 3, &c.

3. *Indentation.*—The ultimate indentation can only be approximately obtained during experiments on punching; it varies directly as the thickness of the plates. For flat-faced punches we may assume it to be one-half the thickness, and for round-faced punches the whole thickness of the plate, when the thickness of the plates is less than the diameter of the shot.

4. *Dynamic resistance, or resistance to projectiles.*—The dynamic resistance varies as the product of the statical resistance and the ultimate indentation of the plates. But both these quantities vary nearly as the thickness of the plates, directly. Hence the dynamic resistance varies in a ratio which is nearly that of the squares of the thicknesses of the plates. So that if the thicknesses be as 1, 2, 3, 4, &c., the dynamic resistances will be as 1, 4, 9, 16, &c. And the dynamic resistances will be nearly twice as great for round- as for flat-faced projectiles.

7. *Computation of a general Formula for the Resistance of Iron Plates to Projectiles.*

Assuming the laws stated above as the result of the experiments on punching, the following formula has been deduced by equating the dynamic resistance to the work accumulated in the shot.

Let t be the thickness of the plate in inches, w the weight of the shot in lbs., v the velocity of the shot at the moment of impact in feet per second, r the semidiameter of the shot; then, from the experiments at Shoeburyness,

$$t=\sqrt{\frac{wv^2}{3374940\,r}} \text{ . . . . } (1.)$$

$$\frac{w}{r}=\frac{3374940\,t^2}{v^2} \text{ . . . . } (2.)$$

From the first of these formulæ we can find the greatest thickness which will be penetrated by a shot of a given size and at a known velocity. From the second we obtain the coordinate values of the weight and size of the shot necessary to punch a plate of a given thickness. The formulæ are only approximate, but they are as accurate as is necessary until the velocity of the shot at impact has been more closely ascertained. It will then be time to determine what modification is necessary to secure an entire agreement with the experimental results. It may be stated, however, that the formulæ do not apply to those cases in which brittle plates break up by transverse flexure.

As respects the fastening of armour-plates, the Committee on Iron have been inundated with schemes from all quarters, but none of them have as yet met the requirements of the case; and until further experiments are tried to equalise the resistance of the fastenings to the resistance of the plates, we are unable to look forward to anything approaching satisfactory results. Bolts and nuts have been tried, and found defective. Strong countersunk rivets have been used, with better success when the plates are attached without wood or any other intervening substance to the skin of the ship; but even these have been found defective, and are inadmissible when a lining of oak or teak intervenes between the armour-plates and the sides of the ship. An ingenious contrivance has been recommended by Mr. Scott Russell for attaching the armour-plates to the ship, and that is a series of bars, in the form of the letter T_a, along the sides of the vessel, between the joints of the armour-plates and the web part a, projecting about an inch and a half beyond the thickness of the plates, heated by a large blowpipe and riveted continuously over the edge of each plate. This system of fastening answers well, but can only apply to ships composed entirely of iron, and when the shield-plates rest directly upon the sides of the ship. Extended experiments are yet required to solve this difficult question, and we have every reason to believe they will not be wanting, when other conditions connected with the changes now in progress have been realized.

Continuation of Report to determine the Effect of Vibratory Action and long-continued Changes of Load upon Wrought-Iron Girders. By William Fairbairn, *Esq., LL.D., F.R.S., &c., President of the Association.*

At the close of the Oxford Meeting it was announced that the experiments on this important subject were still in progress, and that hopes were entertained that they might be completed in time for the Manchester Meeting. Confirmatory of that promise, we have now to submit the results of a still more extended inquiry into the effects of vibratory action on molecular construction. It will be in the recollection of the Meeting that, fifteen years ago, experiments were made which led to the designs and construction of the Conway and Britannia Tubular Bridges, on the Chester and Holyhead

Railways. Since that time some thousands of bridges have been built entirely of wrought iron. The introduction of a new material, and the uncertainty of its durability, led the Board of Trade to determine that the strain should not exceed 5 tons per square inch on any part of the structure. These requirements appeared to be founded on no fixed principle; and the bridge recently erected across the River Spey having been objected to as not in accordance with this standard, it was resolved (with the consent and at the expense of the Board of Trade) that the question whether the continuous changes of load, and the vibration by which they were accompanied, did or did not lead to fracture. This was the question for solution; and the experiments now recorded have in a great measure determined to what extent bridges of this kind can be loaded without incurring danger from fracture.

It is well known that the power of resistance to strain of wrought-iron plates in combination depends upon the principle on which they are united; and unless the parts are permanently established, the five-ton tensile strain per square inch might lead to error. For the purpose of ascertaining the effects of the changes of load and vibration causing rupture, a small iron-plate beam of 20 feet clear span, and 16 inches deep, representing the proportions of one of the girders of the Spey Bridge, was constructed, and exposed to strains and conditions similar to those produced by the passage of heavy trains over a girder bridge.

The beam, as already described (page 46 of the Report of the Oxford Meeting), was first loaded with one-fourth its breaking weight, and with this load it sustained about one million changes without injury. The load was then increased to nearly one-half the breaking weight, when it broke after 5175 changes. From this it appeared that bridges were not safe when loaded to one-half the weight that would break them*. Having arrived at this result, the beam was taken down and repaired, and the experiments renewed with two-fifths the breaking weight, when 158 changes were made to bring the parts repaired to their bearing. The load was then reduced from 4·6785 tons to 3·54 tons, when 25,900 changes were effected. After this the load was again reduced to 3 tons, one-fourth the breaking weight, when 3,150,000 changes were recorded. Ultimately the load was increased to 4 tons, or one-third the breaking weight, when it broke by tension across the bottom flange after sustaining 313,000 changes of that load.

In calculating the strain on the area of the metal after deducting the rivet-holes, which, it must be remembered, were larger in proportion in the small beam than in bridges full size, it was ascertained that the beam suffered no deterioration with strains of 7½ tons per square inch; but with 10 tons it broke with only 5172 changes, as may be seen in the following Tables of experiments.

Table IV.—Beam repaired.

The beam broken in the preceding experiment was repaired by replacing the broken angle-iron on each side, and putting a patch over the broken plate equal in area to the plate itself. Thus repaired, a weight of 3 tons was placed on the beam—equivalent to one-fourth of the breaking weight; that is,

Lever	4470 lbs.
Shackles	74 „
Half weight of beam	1815 „
Scale and 8 lbs.	434 „
	6793

With this weight the experiments were continued as before.

* See Report of Thirtieth Meeting, page 48.

TABLE IV.

Date.	Number of changes of load.	Deflection in inches.	Remarks.
1860. Aug. 9	158		The load, during these changes, was equivalent to 10,500 lbs., or 4·6875 tons, at the centre.
Aug. 11	12,950		During these changes the load on the beam was 8025 lbs., or 3·54 tons.
„ 13	25,900	·22	
Aug. 13	25,900	·18	
„ 16	46,326	·18	
„ 20	71,000	·18	Load reduced to 3 tons, or one-fourth the breaking weight.
„ 24	101,760	·18	
„ 25	107,000	·18	
„ 31	135,260	·18	
Sept. 1	140,500	·18	
„ 8	189,500	·18	
„ 15	242,860	·18	
„ 22	277,000	·18	
„ 30	320,000	·18	
Oct. 6	375,000	·18	
„ 13	429,000	·18	
„ 20	484,000	·18	
„ 27	538,000	·18	
Nov. 3	577,800	·18	
„ 10	617,800	·18	
„ 17	657,500	·18	
„ 23	712,300	·18	
Dec. 1	768,100	·18	
„ 8	821,970	·18	
„ 15	875,000	·18	
„ 22	929,470	·18	
„ 29	1,024,500	·18	
1861. Jan. 9	1,121,100	·18	
„ 19	1,214,000	·18	
„ 26	1,278,000	·18	
Feb. 2	1,342,800	·18	
„ 11	1,426,000	·18	
„ 16	1,485,000	·18	
„ 23	1,543,000	·18	
March 2	1,602,000	·18	
„ 9	1,661,000	·18	
„ 16	1,720,000	·17	
„ 23	1,779,000	·17	
„ 30	1,829,000	·17	
April 6	1,885,000	·17	
„ 13	1,945,000	·17	
„ 20	2,000,000	·17	
„ 27	2,059,000	·17	
May 4	2,110,000	·17	
„ 11	2,165,000	·17	
„ 20	2,250,000	·17	
Sept. 4	2,727,754	·17	
„ 16	3,150,000	·17	

TABLE V.

Date.	Number of changes of load.	Deflection in inches.	Remarks.
Sept. 18, 1861.	0	·2	The weight was again changed, being increased to 4 tons on the beam, equal to ⅓ of breaking weight. Beam broke across the bottom web.
" 19 "	4,000	·2	
Nov. 18 "	126,000	·2	
Dec. 18 "	237,000	·2	
Jan. 9, 1862.	313,000		

Summary of Results.

Table.	Ratio of load to breaking weight.	Number of changes with each load.	Total number of changes of load.	Deflection in inches.	Remarks.
No. I.	1 : 4.0	596,790	596,790	0·17	
II.	1 : 3·4	403,210	1,000,000	0·22	
III.	1 : 2·5	5,175	1,005,175	0·35	Broke.
IV.	1 : 2·56	12,950	12,950	Not recorded	
"	1 : 3·39	12,950	25,900	0·22	
"	1 : 4·00	3,124,101	3,150,000	0·18	
V.	1 : 3·00	313,000	3,463,000	0·28	Beam broke across the bottom web.

From the above it would appear that, within the limits of one-fourth the breaking weight, wrought-iron beams are perfectly safe, as may be seen from the results of Tables I. and II., where 1,000,000 changes were effected without any visible deterioration of the material; and if we add to this the results of Table IV., we have upwards of 4,000,000 changes, which, at 30 trains per diem over the Spey Bridge, would be equivalent to the prolonged period of 400 years. Now as we do not advise bridges to be loaded beyond one-sixth of the load that would break them, we may reasonably consider them perfectly secure for a much longer period of time. Much, however, depends on the quality of the material, and a sound principle of uniting the joints, all of which have been determined by experiment when devising the plans and designs for the Britannia and Conway Tubular Bridges. To these we may safely refer, and above all to the selection of the material, which in those parts of girders subjected to a tensile strain should be of the *best double wrought plates*, and equal to a test of 22 to 24 tons per square inch. The use of this superior quality of iron for the bottom flanges of girders would give an increase of one-tenth of strength to that of common boiler plates.

There is no economy in the use of inferior material for this purpose; as its employment is attended not only with loss of character, but is highly dangerous as regards the public safety.

The Law of Patents.

MR. JAMES HEYWOOD, M.A., F.R.S., read the Report of the Committee on the Patent Laws, which was founded upon, and embodied the following resolutions, agreed upon by the Patent Committee in London:—

1. That all applications for grants of letters patent should be subjected to a preliminary investigation before a special tribunal.

2. That such tribunal shall have power to decide on the granting of patents, but it shall be open to inventors to renew their applications notwithstanding previous refusal.

3. That the said tribunal should be formed by a permanent and salaried judge, assisted when necessary by the advice of scientific assessors, and that its sittings should be public.

4. That the same tribunal should have exclusive jurisdiction to try patent causes, subject to a right of appeal.

5. That the jurisdiction of such tribunal should be extended to the trial of all questions of copyright and registration of design.

6. That the scientific assessors for the trial of patent causes should be five in number (to be chosen from a panel of thirty to be nominated by the Commissioners of Patents), for the adjudication of facts, when deemed necessary by the judge or demanded by either of the parties.

7. That the right of appeal should be to a Court of the Exchequer Chamber, with a final appeal to the House of Lords.

8. That for the preliminary examination, the assessors (if the judge requires their assistance) should be two in number, named by the Commissioners of Patents from the existing panel; the decision to rest with the judge.

9. That the Committee approve of the principle of compelling patentees to grant licenses on terms to be fixed by arbitration, or in case the parties shall not agree to such arbitration, then by the proposed tribunal or by an arbitrator or arbitrators appointed by the said tribunal.

It would be seen, Mr. Heywood said, that the recommendations of the Committee were very important, as they proposed the appointment of a special tribunal. He presumed the cost would be defrayed out of the £70,000 which was annually realized by the granting of patents, after the law officers of the Crown and other officials had received their fees; but at the present time a large proportion of this sum was, he believed, applied to the reduction of the taxation of the country.

Resolutions passed at a meeting of the Committee of the Manchester Patent Law Reform Association, held on the 30th of August, 1861, the Mayor of Manchester in the chair. Communicated by N. S. Hughes.

"That in consequence of very peculiar views propounded by certain persons, that inventors have no claim to remuneration for their inventions, however good and useful; that the value of an invention must not be considered in reference to the benefit of the inventor, but its utility to the public; and that the inventive genius of man does not require any stimulus nor deserve any reward. These novel doctrines, in connexion with the Meeting of the British Association and the Great Exhibition of next year, have caused the Committee of the Manchester Patent Law Reform Association to reconsider the views and resolutions they have so often discussed and adopted at their numerous meetings since 1850. Without intending to justify the present laws in all their details, knowing the many defects which this Committee advocated previous to the alteration in the Patent Laws in 1852, but which, owing to the mischievous opinions of misdirected parties, were overthrown, and consequently remain to be remedied, they consider it their duty to record a few of the Resolutions extracted from the minutes of their proceedings, which have been discussed and considered in every shape and form, both in committee and in public meetings assembled frequently in the Town Hall in this city:—

"1. That it is universally acknowledged that discoveries, inventions, and improvements relating to mechanical and chemical science have very greatly conduced to the civilization of mankind, the progress of commerce, and the wealth of nations.

"2. That the ingenuity of Englishmen especially has effected many valuable inventions and improvements in almost every department of science and manufactures, whereby the commerce, wealth, and power of the British dominions have been promoted to an extent unparalleled in the annals of any other nation.

"3. That in order to develope to the fullest extent the inventive talents of our countrymen, every encouragement and security should be given to inventors consistent with the public welfare.

"4. That the present very heavy expenses, loss of time, and other inconveniences, occasioned by the intricate routine or operation of passing through a great number of useless forms to which the inventor is subjected in obtaining letters patent, exhibit a tendency not calculated to encourage, but absolutely to baffle and paralyze the efforts of a class so essential in maintaining the commercial pre-eminence of this kingdom.

"5. That for many of the most valuable discoveries and inventions, this country is indebted to the expansive minds of operatives and individuals in humble life, who are prevented from securing to themselves the advantages of their inventions on account of the present expensive process of obtaining protection by royal letters patent.

"6. That inventors should not, in obtaining patent right for their inventions, be burdened with any more expenses than such as may be absolutely necessary for the establishment and maintenance of one government office and for publishing full particulars of all patents granted.

"7. That for want of an official record of patents easy of access to the public, many patents are taken out for the same invention, to the serious loss and discouragement of patentees and manufacturers.

"8. That the practice of allowing six months to specify the particulars of inventions, for which letters patent have been granted, operates very injuriously both to patentees and the public, is a source of constant annoyance to persons contemplating patents for inventions, and gives rise to much useless, frivolous, and expensive litigation.

"9. That the present state of the law involves an expensive, dilatory, inconvenient and uncertain mode of obtaining redress in cases of infringement of patent right; that the Judges of the land have been frequently at variance in their decisions, and that juries are seldom found qualified to understand the matters in dispute.

"10. That Commissioners be substituted for the law officers of the Crown, to consist of one person eminently conversant with mechanics, and one conversant with chemistry; the third, in order to form a quorum, to be a barrister, or, if necessary, one of the law officers.

"11. That the juries to try patent cases shall be scientific men, conversant with the subject in dispute.

"It will be seen from the above extracts that some of the suggestions were embodied in the Patent Law Amendment Act of 1852, viz. a very great reduction in the cost of obtaining letters patent, a simplification of the process of application, and the publication of all specifications recorded, forming one of the most complete libraries of invention and scientific progress extant; but still this Committee is well aware that further improvements are necessary; and, in considering such further improvements, the interests of the public and the inventor must be taken jointly, and not separately."

Report on the Theory of Numbers.—Part III. *By* H. J. Stephen Smith, *M.A., F.R.S., Savilian Professor of Geometry in the University of Oxford.*

(B) *Theory of Homogeneous Forms.*

79. *Problem of the Representation of Numbers.*—A rational and integral homogeneous function (a *quantic* according to the nomenclature introduced by Mr. Cayley), of which the coefficients are integral numbers, is, in the Theory of Numbers, termed a *form* (Disq. Arith. art. 266). The form is linear, quadratic, cubic, biquadratic or quartic, quintic, &c., according to its order in respect of the indeterminates it contains; and binary, ternary, quaternary, &c., according to the number of its indeterminates. Thus x^2+y^2 is a binary quadratic form, $x^3+y^3+z^3-3xyz$ a ternary cubic form. A form is considered to be given, when its coefficients are given numbers; and a number is said to be *represented* by a given form, when integral values are assigned to the indeterminates of the form, such that the form acquires the value of the number. If the values of the indeterminates are relatively prime, the representation is said to be *primitive*; if they admit any common divisor beside unity, it is a *derived* representation. Thus 13 and 8 can be represented by x^2+y^2; for $3^2+2^2=13$, $2^2+2^2=8$; and the first of these representations is primitive, the second is derived. The first general problem, then, that presents itself in this part of the Theory of Numbers, is the following, "To find whether a given number is or is not capable of representation by a given form, and, if it is, to find all its representations by that form." The number of different representations of a given number by a given form may be either finite or infinite; in the former case the complete solution of the problem of representation consists in the actual exhibition of the different sets of values that can be given to the indeterminates of the form: in the latter case it consists in assigning general formulæ, in which all those values are comprised. It is in either case sufficient to consider primitive representations only; for if the given form f be of order m, and the given number N be divisible by the m^{th} powers $d_1^{\,m}$, $d_2^{\,m}$, ..., the derived representations of N by f coincide with the primitive representations of $\frac{N}{d_1^{\,m}}$, $\frac{N}{d_2^{\,m}}$, ... by the same form.

80. *Problems of the Transformation and Equivalence of Forms.*—A form $f_2(x'_1, x'_2, \ldots . x'_n)$ is said to be *contained* in another form $f_1(x_1, x_2, \ldots . x_n)$, when f_2 arises from f_1 by a linear transformation of the type

$$\begin{aligned} x_1 &= a_{1,1}x'_1+a_{1,2}x'_2+\ldots\ldots+a_{1,n}x'_n, \\ x_2 &= a_{2,1}x'_1+a_{2,2}x'_2+\ldots\ldots+a_{2,n}x'_n, \\ &\cdots\cdots\cdots\cdots\cdots \\ x_n &= a_{n,1}x'_1+a_{n,2}x'_2+\ldots\ldots+a_{n,n}x'_n, \end{aligned}$$

in which the coefficients $a_{i,j}$ are integral numbers and the determinant is different from zero*. This transformation we may, for brevity, describe as the transformation $|a|$. When $|a|$ is a unit-transformation, *i. e.* when the determinant of $|a|$ is a positive or negative unit, the inverse transformation

* Gauss says that f_2 is contained in f_1, even when the determinant of transformation is zero (Disq. Arith. art. 215). But we shall find it more convenient to retain the restriction specified in the text.

of $|a|$, which will be a transformation of the same type as $|a|$, will have all its coefficients integral numbers; so that in this case f_1, which contains f_2, is also contained in it. When each of two forms is thus contained in the other, they are said to be *equivalent*. If f_1 contain f_2, and f_2 contain f_3, f_1 will contain f_3; for if f_1 be changed into f_2 by the transformation $|a|$, and f_2 into f_3 by the transformation $|b|$, it is clear that f_1 will be changed into f_3 by a transformation $|T|$, of which the constituents are defined by the equation

$$T_{i,j}=a_{i,1}b_{1,j}+a_{i,2}b_{2,j}+\ldots\ldots+a_{i,n}b_{n,j}.$$

The transformation $|T|$ is said to be *compounded* of the transformations $|a|$ and $|b|$, and this composition is expressed by the symbolic equation

$$|T|=|a|\times|b|,$$

in which it is to be observed that the order of the symbols $|a|$ and $|b|$ is not, in general, convertible. When, in particular, f_1 is equivalent to f_2, and f_2 to f_3, f_1 is equivalent to f_3; *i. e.* forms which are equivalent to the same form are equivalent to one another. All the forms, therefore, which are equivalent to one and the same form, may be considered as forming a *class*. All the invariants of any two equivalent forms have the same values; but it is not true, conversely, that two forms which have the same invariants are necessarily equivalent. Nevertheless it may be conjectured that all forms of the same sort (*i. e.* of the same degree, and the same number of indeterminates), the invariants of which have the same values, distribute themselves into a finite number of classes; and this conjectural proposition is certainly true for binary forms of all orders, and for quadratic forms of any number of indeterminates. It is readily seen that if a number be capable of representation by one of two equivalent forms, it is also capable of representation by the other; and that the number of representations is either finite for both, or infinite for both, and, if finite, is the same for each. The general problem, therefore, of the representation of numbers (which we have already enunciated) suggests naturally the following, which we may term that of the equivalence of forms: "Given two forms (of the same sort), of which the invariants have equal values, to find whether they are, or are not, equivalent, and if they are, to assign all the transformations of either of them, into the other." The number of transformations may be either finite or infinite; if finite, the transformations themselves, if infinite, general formulæ containing them, are required for the complete solution of the problem.

When f_1 is not equivalent to, but contains f_2, the invariants of f_2 are derived from those of f_1 by multiplication with certain powers of the *modulus* (*i. e.* of the determinant) of the transformation by which f_1 is changed into f_2; viz. if I be an invariant of f_1, and if i and m be the orders of I, and of f_1 or f_2, the corresponding invariant of f_2 is $a^{\frac{mi}{n}}\mathrm{I}$, a denoting the modulus of transformation, and the number $\frac{mi}{n}$ being always integral. This observation enables us to enunciate with precision a problem in which the preceding is included: "Given two forms, of which the invariants have values consistent with the supposition that one of them contains the other, to find whether this supposition is true or not, and, if it is, to find all the transformations of the one form into the other." But, in every case, the solution of the problem in this more general form may be made to depend on the solution of the problem of equivalence. For every transformation of order n, and modulus a, arises, in one way and in one only, from the composition of two transformations $|a|$ and $|v|$, of which the latter is a unit-transformation, and the former one of the finite number of transformations included in the formula

$$\left|\begin{matrix} \mu_1, & k_{1,2}, & k_{1,3} \ldots\ldots & k_{1,n} \\ 0, & \mu_2, & k_{2,3} \ldots\ldots & k_{2,n} \\ 0, & 0, & \mu_3 \ldots\ldots & k_{3,n} \\ \cdot & \cdot & \cdot & \cdot \\ 0, & 0, & 0 \ldots\ldots & \mu_n \end{matrix}\right| \quad \ldots\ldots\ldots \quad (C.)$$

in which $\mu_1 \times \mu_2 \times \ldots\ldots \times \mu_n = a$, and $0 \leqq k_{i,j} < \mu_i$ (Phil. Trans. vol. cli. p. 312). To determine, therefore, whether the form f_1 can be transformed into f_2 by a transformation of modulus a, we apply to f_1 all the transformations (C.) in succession, obtaining a series of transformed forms $\phi_1, \phi_2, \ldots\ldots$ If none of the forms ϕ are equivalent to f_2, f_1 cannot contain f_2; but if one or more of the forms ϕ be equivalent to f_2, f_1 will contain f_2, and all its transformations into f_2 may be obtained as soon as the transformations of the forms ϕ into f_2 have been determined. This is the method proposed by Gauss for binary quadratic forms (Disq. Arith. arts. 213, 214); it is evidently of universal application; but the following modification of it possesses a certain advantage. Instead of representing $|T|$ by the formula $|T| = |a| \times |v|$, we may employ the formula $|T| = |v| \times |a|$, in which $|v|$ is a unit-transformation as before, and $|a|$ is one of the transformations included in the formula (C.), where, however, the inequality $0 \leqq k_{i,j} < \mu_i$ is to be replaced by $0 \leqq k_{i,j} < \mu_j$; the transformations thus defined we shall call the transformations (C′.). If we now apply to f_2 the inverse of each transformation included in (C′.), we shall obtain a series of forms $\phi_1, \phi_2, \phi_3 \ldots\ldots$ of which the coefficients will not necessarily be integral numbers, because the coefficients of the inverse transformations are not necessarily integral. If all the forms $\phi_1, \phi_2, \ldots\ldots$ be fractional, or if none of those which are integral be equivalent to f_1, f_1 cannot contain f_2; but if some of them be integral, and equivalent to f_2, it is plain that f_1 contains f_2, and that all the transformations of f_1 into f_2 may be obtained by means of the transformations of f_1 into those forms ϕ which are equivalent to it. The advantage above referred to consists in the circumstance that the rejection of the fractional forms ϕ diminishes the number of the problems of equivalence which must be solved to obtain the complete solution of the question proposed (compare Disq. Arith. art. 284, and note).

81. *Automorphic Transformations.*—The unit-transformations by which a form passes into itself are the automorphics of the form; thus $\left|\begin{matrix} 2, & 3 \\ 1, & 2 \end{matrix}\right|$ is an automorphic of $x^2 - 3y^2$. When every invariant of a form is zero, the form may pass into itself by transformations of which the modulus is different from unity; for example, $x^2 - 4xy + 4y^2$, a binary quadratic form of which the discriminant is zero, passes into itself by the transformation $\left|\begin{matrix} 3, & 2 \\ 1, & 2 \end{matrix}\right|$, of which the modulus is 4. In like manner it is to be observed that when two forms of the same sort have all their invariants equal to zero, it may happen that each of them passes into the other by transformations of which the modulus is not a unit. But in this Report we shall have no occasion to consider these exceptional cases, whether of equivalence or of automorphism, and we shall therefore employ these terms with reference to unit-transformations exclusively. If $|T_1|$ and $|T_2|$ be automorphics of a form f, $|T_1| \times |T_2|$ and $|T_2| \times |T_1|$ are also automorphics of f; so that, in particular, every power

of an automorphic is also an automorphic. (The positive powers of a transformation are, of course, the transformations which arise from compounding it continually with itself; its negative powers are the positive powers of its inverse. See Mr. Cayley's Memoir on the Theory of Matrices, Phil. Trans. vol. cxlviii. p. 17.) Hence, if a form have a single automorphic, of which no two powers are identical, it will have an infinite number of automorphics. The importance of automorphic transformations in the solution of the problems of equivalence and transformation will be apparent from the following considerations. If f_1 and f_2 be two equivalent forms, $|h|$ a given transformation of f_1 into f_2, $|\alpha_1|$ and $|\alpha_2|$ the general formulæ representing all the automorphics of f_1 and f_2 respectively, all the transformations of f_1 into f_2 will be represented by either of the formulæ $|\alpha_1|\times|h|$ or $|h|\times|\alpha_2|$. And again, if f_1 contain f_2, and if we represent by $|h_1|, |h_2|, \ldots$ certain particular transformations of f_1 into f_2, obtained by compounding each transformation (C), which gives a form ϕ equivalent to f_2, with some one transformation of ϕ into f_2, then all the transformations of f_1 into f_2 will be comprised in a finite number of formulæ of the type

$$|h_1|\times|\alpha_2|, \quad |h_2|\times|\alpha_2|, \quad |h_3|\times|\alpha_2|, \ldots\ldots\ldots,$$

$|\alpha_2|$ still denoting indefinitely any automorphic of f_2. Or, if we employ the second method of the preceding article, the same transformations will be represented by

$$|\alpha_1|\times|h_1'|, \quad |\alpha_1|\times|h_2'|, \quad |\alpha_1'|\times|h_3'|, \ldots\ldots\ldots,$$

where $|\alpha_1|$ is any automorphic of f_1, and $|h_1'|, |h_2'|, |h_3'|, \ldots\ldots$ are certain particular transformations of f_1 into f_2, obtained in a manner sufficiently indicated by the method itself. It appears, therefore, that when we know all the automorphics either of f_1 or f_2, we can deduce all the transformations of f_1 into f_2, from one of those transformations when f_1 is equivalent to f_2, and from a certain finite number of them when f_1 contains, but is not equivalent to, f_2. We may add, that when one transformation of two equivalent forms, and the automorphics of either of them are known, those of the other are known also, for we evidently have the equation

$$|\alpha_2|=|h|^{-1}\times|\alpha_1|\times|h|.$$

82. *Problem of the Representation of Forms.*—We give the enunciation of one other general problem, which may be said to occupy a middle place between the problems of the representation of numbers, and of the equivalence of forms. By using a *defective* substitution of the type

$$\begin{aligned}
x_1&=a_{1,1}x'_1+a_{1,2}x'_2+\ldots\ldots\ldots a_{1,n-2}x'_{n-r},\\
x_2&=a_{2,1}x'_1+a_{2,2}x'_2+\ldots\ldots\ldots a_{2,n-2}x'_{n-r},\\
&\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\\
x_n&=a_{n,1}x'_1+a_{n,2}x'_2+\ldots\ldots\ldots a_{n,n-2}x'_{n-r},
\end{aligned}$$

a form $f_1(x_1,x_2,\ldots\ldots x_n)$ may be changed into another $f_2\,(x'_1, x'_2, \ldots\ldots x'_{n-r})$ of the same order but containing fewer indeterminates. The form f_2 is said to be *represented* by f_1; and the representation is *proper* or *improper* according as the determinants of the system do not, or do admit of any common divisor besides unity. Our third general problem therefore is, "Given two forms of the same order, of which the first contains more indeterminates than the second, to find whether the second can be represented (properly or improperly) by the first, and, if it can, to assign all the representations of which it is susceptible." If the second form contain only one indeterminate (*i. e.* if it be an expression of the form Ax^n), the problem reduces itself to that of the representation of the number A by the form f_1. If, again, f_2 contains as many indeterminates as f_1, the problem becomes that of the transformation of f_1 into f_2. We may add that the problem of improper representation may be made to depend on that of proper representation, by methods analogous to those by which the problem of transformation depends on that of equivalence. (See Disq. Arith. art. 284, where Gauss treats of the improper representation of binary by ternary quadratic forms.)

83. It is hardly necessary to state that what has been done towards obtaining a complete solution of these problems is but very little compared with what remains to be done. Our knowledge of the algebra of homogeneous forms (notwithstanding the accessions which it has received in recent times) is far too incomplete to enable us even to attempt a solution of them co-extensive with their general expression. And even if our algebra were so far advanced as to supply us with that knowledge of the invariants and other concomitants of homogeneous forms which is an essential preliminary to an investigation of their arithmetical properties, it is probable that this arithmetical investigation itself would present equal difficulties. The science, therefore, has as yet had to confine itself to the study of particular sorts of forms; and of these (excepting linear forms, and forms containing only one indeterminate) the only sort of which our knowledge can be said to have any approach to completeness are the binary quadratic forms, the first in order of simplicity, as they doubtless are in importance. Of all other sorts of forms our knowledge, to say the least, is fragmentary.

We shall arrange the researches of which we have now to speak in the following order, according to the subjects to which they refer:—

1. Binary Quadratic Forms.
2. Binary Cubic Forms.
3. Other Binary Forms.
4. Ternary Quadratic Forms.
5. Other Quadratic Forms.
6. Forms of order n decomposable into n linear factors.

The theory of linear forms (*i. e.* of linear indeterminate equations) we shall refer to hereafter. That of forms containing only one indeterminate will not require any further notice.

(1) *Binary Quadratic Forms.*

84. Instead of confining our attention exclusively to the most recent researches in the Theory of Quadratic Forms, we propose, in the following articles, to give a brief but systematic *résumé* of the theory itself, as it appears in the Disq. Arith., introducing, in their proper places, notices, as full as our limits will admit, of the results obtained by later mathematicians. We adopt this method, partly to render the later researches themselves more easily intelligible, by showing their connexion with the whole theory; but partly also in the hope of facilitating to some persons the study of the Fifth Section of the Disq. Arith., which, probably owing to the obscurity of certain parts of it, is even now too much neglected by mathematicians. This section is composed, as Lejeune Dirichlet has observed (Crelle, vol. xix. p. 325), of two very distinct parts. The results contained in the former of the two (arts. 153–222) are for the most part those which had been already obtained by Euler, Lagrange, and Legendre; but they are completed in many respects; they are derived, in part at least, from different principles,

and are expressed in a terminology which has been adopted by most subsequent writers. The second part (arts. 223–307) is occupied, after some preliminary disquisitions (arts. 223–233), with the ulterior researches of Gauss himself. We proceed then to give a summary of the definitions and theorems contained in the first of these two portions.

85. *Elementary Definitions.*—The quadratic form $ax^2+2bxy+cy^2$ is symbolized by the formula $(a, b, c)(x, y)^2$, or, when it is not necessary to specify the indeterminates, by the simpler formula (a, b, c). The second coefficient is always supposed to be even; and an expression of the form $px^2+qxy+ry^2$ (in which q is uneven) is not considered by Gauss as itself a quadratic form, but as the half of the quadratic form $(2p, q, 2r)$. The discriminant b^2-ac of the form (a, b, c) is called by Gauss the *determinant* of the form; an expression which at the present time it would be neither possible nor desirable to alter. When two forms are equivalent, they are said to be *properly* equivalent if the modulus of transformation is $+1$, but *improperly* equivalent if it is -1. Only those forms which are properly equivalent to one another are considered to belong to the same class; two forms which are only improperly equivalent are said to belong to *opposite* classes. This distinction between proper and improper equivalence is due to Gauss, and is of very great importance. In what follows, unless the contrary is expressly specified, we shall use the terms equivalence and automorphism to denote proper equivalence and proper automorphism. It is readily seen that the greatest common divisors of a, $2b$, c, and of a, b, c are the same for (a, b, c) and for every form equivalent to (a, b, c); if each of those greatest common divisors is unity, (a, b, c) is a *properly primitive* form, and the class of forms equivalent to (a, b, c) a properly primitive class; if the first greatest common divisor be 2, and the second 1, the form, and the class of forms equivalent to it, are termed *improperly primitive.* Every form which is not itself primitive, is a numerical multiple of some primitive form of a less determinant, and is therefore called a derived form. Thus x^2+3y^2 is a properly primitive form of det. -3, $2x^2+2xy+2y^2$ is an improperly primitive form of the same determinant; while $2x^2+6y^2$, $4x^2+4xy+4y^2$ are derived forms of det. -12.

In all questions relating to the representation of numbers, or the equivalence of forms, it is sufficient to consider primitive forms, as the solution of these problems for derived forms is immediately deducible from their solution for primitive forms; but in certain investigations connected with the transformation of forms the consideration of derived forms is indispensable. (The problem of art. 82 coincides with that of the representation of numbers, in the case of binary forms of any order.)

The nature of the quadratic form (a, b, c) depends very mainly on the value of its determinant, which we shall symbolize by D. (1) If $D=0$, the form (a, b, c) reduces itself to an expression of the type $m(px+qy)^2$, p and q denoting two numbers relatively prime, and m being the greatest common divisor of a, b, c. The arithmetical theory of such expressions, which are not binary forms at all, since they are adequately represented by a formula such as mX^2, is so simple, and at the same time diverges so much from that of true binary quadratic forms, that we shall not advert to it again in this Report, and in all that follows the determinant is supposed to be different from zero. (2) When D is a perfect positive square, the form (a, b, c) reduces itself to an expression of the type $m(p_1x+q_1y)(p_2x+q_2y)$, *i. e.* it becomes a product of two linear forms. Owing to this circumstance the theory of forms of a square determinant is so much simpler than that of other quadratic forms, that we shall not enter into any details with regard to them, though it is not necessary to exclude them (as is the case with forms of determinant zero) from those investigations which relate simultaneously to the two remaining kinds of quadratic forms; viz. (3) those of a negative determinant, and (4) those of a positive and not square determinant. An essential difference between these two kinds of forms is, that whereas both positive and negative numbers can be represented by any form of positive and not square determinant, forms of a negative determinant can represent either positive numbers only, or negative numbers only. For if the roots of $a+2b\theta+c\theta^2=0$ be real, it is clear that $ax^2+2bxy+cy^2$ will have values of different signs, when the ratio $y:x$ falls between the two roots and when it falls outside them; but if the roots be imaginary, the form will always obtain values having the same sign (viz. that of a or c), whatever the ratio $y:x$ may be. If (a, b, c) be a positive form (*i.e.* a form representing positive numbers only) of a negative determinant $D=-\Delta$, $(-a, -b, -c)$ is a negative form of the same determinant, and can represent negative numbers only. We see, therefore, that there are as many positive as negative classes for any negative determinant; and as everything that can be said about positive forms or classes may be transferred at once, *mutatis mutandis*, to negative forms and classes, we shall in what follows exclude the latter from consideration, and, when we are speaking of forms of a negative determinant, confine ourselves to the positive forms.

Since x^2-Dy^2, or $(1, 0, -D)$, is a form of determinant D, we see that one class at least of properly primitive forms exists for every determinant; and the class containing the form x^2-Dy^2 is called the principal class. Improperly primitive forms only exist for those determinants which satisfy the condition $D\equiv 1$, mod 4; since, if (a, b, c) be improperly primitive, we have $b\equiv 1$, mod 2, $a\equiv c\equiv 0$, mod 2. But for every determinant satisfying this condition, one class at least of improperly primitive forms exists; for $\left(2, 1, -\frac{D-1}{2}\right)$ is an improperly primitive form of determinant D, and the class containing it may be called the principal class of improperly primitive forms.

86. *Reduction of the Problem of Representation to that of Equivalence.*— The problem of the representation of numbers depends, first, on the solution of a quadratic congruence, and, secondly, on the solution of a problem of equivalence. This dependence is established by the two following theorems:—

(i.) "When the number M admits of a primitive representation by (a, b, c), the quadratic congruence $x^2-D\equiv 0$, mod M, is resoluble."

For if $am^2+2bmn+cn^2=M$ be a primitive representation of M, let μ, ν be two numbers satisfying the equation $m\nu-n\mu=1$; we then find

$$(am^2+2bmn+cn^2)(a\mu^2+2b\mu\nu+c\nu^2)=(am\mu+b[m\nu+n\mu]+cn\nu)^2-D;$$

or $$\Omega^2\equiv D, \text{ mod } M; \text{ if } \Omega=am\mu+b[m\nu+n\mu]+cn\nu.$$

We have already referred to this result in art. 68.

The representation $am^2+2bmn+cn^2$ of the number M by the form (a, b, c), is said by Gauss to appertain to the value Ω of the congruential radical $\sqrt{D}$, mod M. To understand this definition with precision, it is to be observed that if in the expression of Ω we replace μ and ν by any two other numbers satisfying the equation $m\nu-n\mu=1$, the new value of Ω will be of the form $\Omega+kM$; and conversely, values for μ and ν can always be found which shall give to $am\mu+b[m\nu+n\mu]+cn\nu$ any assigned value of the form $\Omega+kM$. Two different representations of M appertaining to the same value of $\sqrt{D}$, mod M, are said to belong to the same *set*.

(ii.) "If M admit of a primitive representation by the form (a, b, c) appertaining to the value Ω of $\sqrt{D}$, mod M, the two forms (a, b, c) and

$$\left(M, \Omega, \frac{\Omega^2-D}{M}\right)$$

are equivalent; and conversely, if these two forms are equivalent, M admits of a primitive representation by (a, b, c) appertaining to the value Ω of $\sqrt{D}$, mod M."

To establish the first part of this theorem, we observe that the assertion that M admits of a primitive representation by the form (a, b, c) appertaining to the value Ω of $\sqrt{D}$, mod M, implies the existence of four numbers m, n, μ, ν, satisfying the equations

$$\left.\begin{array}{l} m\nu-n\mu=1, \\ am^2+2bmn+cn^2=M, \\ am\mu+b[m\nu+n\mu]+cn\nu=\Omega. \end{array}\right\} \quad \ldots\ldots\ldots\ldots\ldots \quad (k)$$

If, therefore, we apply to (a, b, c) the transformation $\begin{vmatrix} m, & \mu \\ n, & \nu \end{vmatrix}$, the resulting form will have M and Ω for its first and second coefficients respectively; its third coefficient will therefore be $\frac{\Omega^2-D}{M}$, because its determinant must be D; *i.e.* the two forms (a, b, c) and $\left(M, \Omega, \frac{\Omega^2-D}{M}\right)$ are equivalent. And, conversely, the equivalence of the two forms (a, b, c) and

$$\left(M, \Omega, \frac{\Omega^2-D}{M}\right)$$

implies the existence of a transformation $\begin{vmatrix} m, & \mu \\ n, & \nu \end{vmatrix}$ of (a, b, c) into

$$\left(M, \Omega, \frac{\Omega^2-D}{M}\right);$$

i.e. it implies the existence of four numbers m, n, μ, ν, satisfying the equations (k); or, finally, of a primitive representation of M by (a, b, c) appertaining to the value Ω of $\sqrt{D}$, mod M.

If (A, B, C) be a form equivalent to a form (a, b, c) by which

$$M=am^2+2bmn+cn^2$$

is represented, and if $\begin{vmatrix} \alpha, & \beta \\ \gamma, & \delta \end{vmatrix}$ be a transformation of (A B C) into (a, b, c), it is clear that

$$(A, B, C)(\alpha m+\beta n, \gamma m+\delta n)^2=(a, b, c)(m, n)^2=M.$$

Two such representations of M by equivalent forms are called *corresponding* representations; and we may enunciate the theorem, "Corresponding representations of the same number M by equivalent forms appertain to the same value of the expression $\sqrt{D}$, mod M," the truth of which is evident from the nature of the function $Am\mu+B[m\nu+n\mu]+Cn\nu$, which is a covariant (in respect of m, n and μ, ν) to $Ax^2+2Bxy+Cy^2$.

To obtain, therefore, all the primitive representations of a given number by a given form (a, b, c), we investigate all the values of the expression $\sqrt{D}$, mod M. If $\Omega_1, \Omega_2, \ldots$ be those values, we next compare each of the forms

$$\left(M, \Omega, \frac{\Omega^2-D}{M}\right)$$

with (a,b,c). If none of them be equivalent to (a,b,c), M does not admit of primitive representation by (a,b,c); but if one or more of them, as $\left(M, \Omega_1, \frac{\Omega_1^2-D}{M}\right)$, be equivalent to (a,b,c), let $\begin{vmatrix} \alpha, \beta \\ \gamma, \delta \end{vmatrix}$ be the formula exhibiting all the transformations of (a,b,c) into $\left(M, \Omega_1, \frac{\Omega_1^2-D}{M}\right)$; then all the primitive representations of M by (a,b,c), which appertain to the value Ω_1 of $\sqrt{D}$, mod M, are contained in the formula $(a,b,c)(\alpha,\gamma)^2=M$.

87. *Determination of the number of Sets of Representations.*—It appears from what has preceded, that if S denote a system of representative forms of determinant D (*i. e.* a system of forms containing one form, and only one, for every class of forms of determinant D), the number of different sets of primitive representations of M by the forms of S is equal to the number of different solutions of the congruence $x^2 \equiv D$, mod M. If, in particular, M be uneven and prime to D, it is clear that M can only be represented by properly primitive forms; and in this case the number of solutions of the congruence $x^2 \equiv D$, mod M, *i.e.* the number of sets of primitive representations of M by the properly primitive forms contained in S, is expressed by either of the two formulæ $\Pi\left(1+\left(\frac{D}{p}\right)\right)$, or $\Sigma\left(\frac{D}{\delta}\right)$, in which p and δ denote respectively the prime divisors of M, and those divisors of M which are divisible by no square; while $\left(\frac{D}{p}\right)$ and $\left(\frac{D}{\delta}\right)$ are the quadratic symbols of Lagrange and Jacobi (see arts 16, 17, 68, 76). If μ denote the number of different primes dividing M, the common value of the two expressions $\Pi\left(1+\left(\frac{D}{p}\right)\right)$ and $\Sigma\left(\frac{D}{\delta}\right)$, is 2^μ or zero, according as the condition $\left(\frac{D}{p}\right)=1$ is satisfied by every prime divisor of M, or is not satisfied by one or more of them. When D is $\equiv 1$, mod 4, S will certainly contain improperly primitive forms; and the unevenly even number 2M (where M is still supposed prime to D) will admit of primitive representation only by the improperly primitive forms contained in S (for if Ω denote any root of the congruence $x^2 \equiv D$, mod 2M, Ω will be uneven, $\frac{\Omega^2-D}{2M}$ even, and the form $\left(M, \Omega, \frac{\Omega^2-D}{2M}\right)$ will be improperly primitive). And the number of sets of primitive representations of 2M by these improperly primitive forms will be the same as the number of sets of primitive representations of M by the properly primitive forms in S.

The problem of obtaining the derived representations of M by (a,b,c) depends on that of finding the primitive representations of a given number by a given form (see art. 79). Two derived representations of M are said to belong to the same set, when the greatest common divisor of the indeterminates, which we will symbolize by ω, is the same for each, and when the two primitive representations of $\frac{M}{\omega^2}$, from which they are derived, appertain to the same value of $\sqrt{D}$, mod $\frac{M}{\omega^2}$. Adopting this definition, we may enunciate the theorem, "If M be an uneven number prime to D, the whole number of sets of representations of M (and if $D \equiv 1$, mod 4, of 2M) by a system of representative forms of determinant D is $\Sigma\left(\frac{D}{d}\right)$; d denoting any divisor of D."

We may add that, as before, M will be represented only by properly primitive forms; and, when $D \equiv 1$, mod 4, 2M only by improperly primitive forms*.

88. *Reduction of the Problem of Transformation to that of Equivalence.*—It has been shown in art. 80, that the general problem, "Given two forms of unequal determinants, to decide whether one of them contains the other, and if so, to find all the transformations of the containing into the contained form," can be reduced to the simpler problem of the equivalence of forms. For the sake of clearness we shall here point out how the first of the two general methods of that article is to be applied to quadratic forms. If of two forms f and F the former contain the latter, the determinant of F is a multiple of that of f by a square number, viz. by the square of the modulus of transformation. Let the determinant of f be D, and that of F, De^2; also let m and μ be any two conjugate divisors of e, so that $m\mu = e$. Then every transformation of which the modulus is e may be expressed in one way, and one only, by the formula $\begin{vmatrix} m, k \\ 0, \mu \end{vmatrix} \times \begin{vmatrix} \alpha, \beta \\ \gamma, \delta \end{vmatrix}$, in which k denotes one of the numbers $0, 1, 2, 3, \ldots m-1$, and $\begin{vmatrix} \alpha, \beta \\ \gamma, \delta \end{vmatrix}$ is any unit-transformation whatever. If, therefore, we apply to the form f all the transformations included in the formula $\begin{vmatrix} m, k \\ 0, \mu \end{vmatrix}$ (of which the number is equal to the sum of the divisors of e), we shall obtain a series of forms $\phi_1, \phi_2, \ldots$ of determinant De^2. If none of these forms be equivalent to F, F is certainly not contained in f; but if one or more of them, for example, ϕ, arising from the transformation $\begin{vmatrix} m, k \\ 0, \mu \end{vmatrix}$, is equivalent to F, let $\begin{vmatrix} \alpha, \beta \\ \gamma, \delta \end{vmatrix}$ represent indefinitely any transformation of ϕ into F; then f passes into F by any one of the transformations included in the formula $\begin{vmatrix} m, k \\ 0, \mu \end{vmatrix} \times \begin{vmatrix} \alpha, \beta \\ \gamma, \delta \end{vmatrix}$. If we take in succession for ϕ every form in the series $\phi_1, \phi_2, \ldots$ which is equivalent to F, it is readily seen that the transformations of f into F, which are thus obtained, are all different, and that they include all possible transformations of f into F.

We have supposed the number e to be positive, *i.e.* we have supposed that f contains F properly. To decide whether f contains F improperly, we have only to examine whether any of the forms $\phi_1, \phi_2 \ldots$ be improperly equivalent to F; and if any one of them be so, to combine the transformation of f into it, with its (improper) transformations into F.

89. *Problem of Equivalence.*—It remains to speak of the problem of equivalence. Of the three parts of which this problem consists, viz. (1) to decide whether two given forms are equivalent or not, (2) if they are, to

* The theorems of this article will not be found in the Disq. Arith. If, in their expression, we transform the symbols $\left(\frac{D}{\delta}\right)$, $\left(\frac{D}{d}\right)$ by the law of reciprocity, we obtain results which coincide with those given by Lejeune Dirichlet in his memoir, "Recherches sur l'application etc.," sect. 7 (Crelle, vol. xxi. p. 1–6).

obtain a single transformation of one form into the other, and (3) from a single transformation to deduce all the transformations, the last only admits of being treated by a method equally applicable to forms of a positive and negative determinant. We shall therefore consider it first. The solution which Gauss has given of it (Disq. Arith. art. 162) depends on principles which are concealed (as is frequently the case in the Disquisitiones Arithmeticæ) by the synthetical form in which he has expressed it. We shall not therefore repeat the details of his solution, but shall endeavour to point out the basis on which it rests.

Let $f=(a, b, c)\ (x, y)^2$ be transformed into $F=(A, B, C)\ (x, y)^2$ by two different, but *similar* transformations, $\begin{vmatrix}\alpha_0, \beta_0\\ \gamma_0, \delta_0\end{vmatrix}$ and $\begin{vmatrix}\alpha_1, \beta_1\\ \gamma_1, \delta_1\end{vmatrix}$; *i.e.* by two transformations of which the determinants are equal in sign as well as in magnitude to the same positive or negative number e. Let also, for brevity,

$$X_0=\alpha_0 x+\beta_0 y,\ Y_0=\gamma_0 x+\delta_0 y,\ X_1=\alpha_1 x+\beta_1 y,\ Y_1=\gamma_1 x+\delta_1 y,$$

so that $f(X_0, Y_0)=f(X_1, Y_1)=F(x,y)$; we have then the algebraical theorem—

"The homogeneous functions $F(x,y)$ and $X_0Y_1-X_1Y_0$ differ only by a numerical factor, not containing x or y."

The truth of this theorem is independent of the supposition that the coefficients of the given forms and given transformations are integral numbers. Its demonstration is implicitly contained in the formulæ given by Gauss; or it may be verified more indirectly by the consideration, that if ω be a root of the equation $a+2b\omega+c\omega^2=0$, we have, simultaneously,

$$\omega=\frac{\gamma_0+\delta_0\Omega}{\alpha_0+\beta_0\Omega},\quad \omega=\frac{\gamma_1+\delta_1\Omega}{\alpha_1+\beta_1\Omega},$$

Ω denoting in each case the *same* root of the equation $A+2B\Omega+C\Omega^2=0$, an assertion which would not be true, if the equal determinants $\alpha_0\delta_0-\beta_0\gamma_0$ and $\alpha_1\delta_1-\beta_1\gamma_1$ were of opposite signs. Hence the equation $\dfrac{\gamma_0+\delta_0\Omega}{\alpha_0+\beta_0\Omega}=\dfrac{\gamma_1+\delta_1\Omega}{\alpha_1+\beta_1\Omega}$ coincides with the equation $A+2B\Omega+C\Omega^2=0$; *i.e.* $X_0Y_1-X_1Y_0$ is identical (if we neglect a factor not containing x or y) with $F(x, y)$.

Comparing this conclusion with the identity

$$\left.\begin{aligned}&[F(x,y)]^2=f(X_0, Y_0)\times f(X_1, Y_1)=\\ &[aX_0X_1+b(X_0Y_1+X_1Y_0)+cY_0Y_1]^2-D(X_0Y_1-X_1Y_0)^2,\end{aligned}\right\}\quad . \quad . \quad (h)$$

we obtain a second result of the same kind—

"The function $aX_0X_1+b(X_0Y_1+X_1Y_0)+cY_0Y_1$ differs from $F(x,y)$ only by a numerical factor not containing x or y."

Let m be the greatest common divisor of A, 2B, and C; U and T the greatest common divisors of the coefficients of x^2, xy, and y^2 in $X_0Y_1-X_1Y_0$ and $aX_0X_1+b(X_0Y_1+X_1Y_0)+cY_0Y_1$ respectively; m being a positive integer, but the signs of U and T being fixed by the equations

$$\frac{F(x,y)}{m}=\frac{X_0Y_1-X_1Y_0}{U}=\frac{aX_0X_1+b(X_0Y_1+X_1Y_0)+cY_0Y_1}{T},\quad . \quad . \quad (k)$$

which are implied by the two algebraical theorems that have preceded; the numbers T, U, and m will satisfy the equation $T^2-DU^2=m^2$, which is obtained by combining the equations (h) and (k), and will serve to express the relation which subsists between the transformations $\begin{vmatrix} \alpha_0, \beta_0 \\ \gamma_0, \delta_0 \end{vmatrix}$ and $\begin{vmatrix} \alpha_1, \beta_1 \\ \gamma_1, \delta_1 \end{vmatrix}$. Solving the equations

$$X_0Y_1 - X_1Y_0 = \frac{U}{m}F(x, y) = \frac{U}{m}f(X_0, Y_0),$$

$$aX_0X_1 + b(X_0Y_1 + X_1Y_0) + cY_0Y_1 = \frac{T}{m}F(x, y) = \frac{T}{m}f(X_0, Y_0)$$

for X_1 and Y_1, we find

$$mX_1 = (T - bU)X_0 - cUY_0,$$
$$mY_1 = aUX_0 + (T + bU)Y_0;$$

or, finally, equating the coefficients of x and y,

$$\begin{vmatrix} \alpha_1, \beta_1 \\ \gamma_1, \delta_1 \end{vmatrix} = \frac{1}{m} \times \begin{vmatrix} T\alpha_0 - U(b\alpha_0 + c\gamma_0), & T\beta_0 - U(b\beta_0 + c\delta_0) \\ T\gamma_0 + U(a\alpha_0 + b\gamma_0), & T\delta_0 + U(a\beta_0 + b\delta_0) \end{vmatrix}$$

$$= \frac{1}{m} \times \begin{vmatrix} T - bU, & -cU \\ aU, & T + bU \end{vmatrix} \times \begin{vmatrix} \alpha_0, \beta_0 \\ \gamma_0, \delta_0 \end{vmatrix} \quad . \; . \; . \; . \; . \; . \; . \quad (C)$$

If we suppose the complete solution of the indeterminate equation $T^2 - DU^2 = m^2$ to be known, the formula (C) supplies us with a complete solution of the problem, "Given one transformation of f into F, to deduce all the similar transformations of f into F." For if we suppose in that formula that T and U denote indefinitely any two numbers satisfying the indeterminate equation, it will appear (1) that every transformation of f into F is contained in (C); (2) that every transformation contained in (C) is a transformation of f into F; (3) that no two transformations contained in (C), and corresponding to different values of T and U, are identical. Only it is to be observed that the transformations (C) are not, in general, all integral. They are so, however, when e, the modulus of transformation, is a unit, a supposition which we have not yet introduced; *i.e.* when the forms f and F are either properly or improperly equivalent; because $\frac{a}{m}$, $\frac{2b}{m}$, and $\frac{c}{m}$ are then evidently integral; whence it may be inferred that $\frac{T+bU}{m}$ and $\frac{T-bU}{m}$ are so too.

90. *Expression for the Automorphics of a Quadratic Form.*—To find the automorphics of any quadratic form it is sufficient to consider the case of a primitive form. Putting then $f = F$, and taking for $\begin{vmatrix} \alpha_0, \beta_0 \\ \gamma_0, \delta_0 \end{vmatrix}$ the identical transformation $\begin{vmatrix} 1, 0 \\ 0, 1 \end{vmatrix}$, we obtain from the formula (C) the following general expression for the automorphics of f,

$$\begin{vmatrix} \alpha, \beta \\ \gamma, \delta \end{vmatrix} = \frac{1}{m} \times \begin{vmatrix} T - bU, & -cU \\ aU, & T + bU \end{vmatrix}, \quad . \; . \; . \; . \; . \; . \quad (D)$$

where $m = 1$, or 2, according as f is properly or improperly primitive. The nature of this expression for the automorphics depends on the value of D. If D be positive and not square, let us represent the least positive numbers satisfying the equation $T^2 - DU^2 = m^2$ by T_1 and U_1; we then have, by a known theorem, the following formula for all the solutions in which T is positive,

$$\frac{T_k+U_k\sqrt{D}}{m}=\left(\frac{T_1+U_1\sqrt{D}}{m}\right)^k,$$

k denoting any positive or negative integral number.

From this we can can infer that if $\begin{vmatrix}\alpha_1, \beta_1\\ \gamma_1, \delta_1\end{vmatrix}$ be the automorphic in the formula (D), arising from the values T_1, U_1 of T and U, all the other proper automorphics are powers of $\begin{vmatrix}\alpha_1, \beta_1\\ \gamma_1, \delta_1\end{vmatrix}$, and are included in the formula

$$|\epsilon| \times \begin{vmatrix}\alpha_1, \beta_1\\ \gamma_1, \delta_1\end{vmatrix}^k,$$

$|\epsilon|$ representing one or other of the identical transformations

$$\begin{vmatrix}1, 0\\ 0, 1\end{vmatrix} \text{ and } \begin{vmatrix}-1, & 0\\ 0, & -1\end{vmatrix}.$$

If D be a negative number, the only solutions of the equation $T^2-DU^2=m^2$ (except in two cases presently to be noticed) are $T=\pm m$, $U=0$. Hence the only proper automorphics of a form of negative determinant are the two identical transformations $\begin{vmatrix}1, 0\\ 0, 1\end{vmatrix}$ and $\begin{vmatrix}-1, & 0\\ 0, & -1\end{vmatrix}$. The two excepted cases are (1) $D=-1$, $m=1$; (2) $D=-3$, $m=2$. In the former case we have for T and U the four values ± 1, 0, and 0, ± 1; whence the proper automorphics of a form of det. -1 are the four transformations supplied by the formula $\begin{vmatrix}-b, & -c\\ a, & b\end{vmatrix}^k$. If $D=-3$, $m=2$, the solutions of $T^2+3U^2=4$ are six in all, viz. $\pm 2, 0$; $\pm 1, 1$; and $\pm 1, -1$; whence six automorphics, comprised in the formula

$$\begin{vmatrix}\frac{1}{2}(1-b), & -\frac{1}{2}c\\ \frac{1}{2}a, & \frac{1}{2}(1+b)\end{vmatrix}^k,$$

exist for an improperly primitive form of det. -3. We may add that in each of these two cases, in addition to the proper automorphics we have found, there exist an equal number of improper automorphics.

From the formula (C), compared with the theory of representation contained in art. 86, it follows that if $(a, b, c)\ (\alpha, \gamma)^2=M$ be any representation of M by (a, b, c), all the representations of the same set are included in the formula $\left[\frac{T\alpha-U(b\alpha+c\gamma)}{m}, \frac{T\gamma+U(a\alpha+b\gamma)}{m}\right]$. For forms of a positive and not square determinant the number of representations in each set is therefore infinite. For forms of a negative determinant the number of representations in each set is, in general, two; and if $[\alpha, \gamma]$ be one of them, the other is $[-\alpha, -\gamma]$. But if the determinant be -1, or if the form be derived from a form of det. -1, the number of representations in each set is four; and if the form be an improperly primitive form of det. -3, or be derived from such a form, the number of representations in each set is six.

91. *Expression for the Automorphics—Method of Lejeune Dirichlet.*—We have inferred the expression (D) of the automorphics of f, from the formula (C) of which it is a particular case. But it is plain, from the general theory of art. 81, that, when f and F are equivalent, we can conversely infer the formula (C) from (D). This method has been preferred by Lejeune Dirichlet, who obtains the automorphics of a primitive form $f=(a, b, c)$, of

which the determinant is not a positive square, by the following process (Crelle, vol. xxiv. p. 324). If $\begin{vmatrix} \alpha, \beta \\ \gamma, \delta \end{vmatrix}$ be any rational automorphic of f, we have evidently

$$a(ax^2+2bxy+cy^2)=[ax+(b+\sqrt{D})y]\quad[ax+(b-\sqrt{D})y],$$
$$=[(a\alpha+[b+\sqrt{D}]\gamma)x+(a\beta+[b+\sqrt{D}]\delta)y]\times$$
$$[(a\alpha+[b-\sqrt{D}]\gamma)x+(a\beta+[b-\sqrt{D}]\delta)y],$$

an equation which, for brevity, we may write

$$(p_1x+q_1y)\ (p_2x+q_2y)=(P_1x+Q_1x)\ (P_2x+Q_2y),$$

and which implies one or other of the two following systems:—

$$(1)\quad p_1p_2=P_1P_2;\quad \frac{p_1}{P_1}=\frac{q_1}{Q_1};\quad \frac{p_2}{P_2}=\frac{q_2}{Q_2},$$

$$(2)\quad p_1p_2=P_1P_2;\quad \frac{p_1}{P_2}=\frac{q_1}{Q_2};\quad \frac{p_2}{P_1}=\frac{q_2}{Q_1}.$$

If (1) be the system which is satisfied by $\begin{vmatrix} \alpha, \beta \\ \gamma, \delta \end{vmatrix}$, let $\frac{p_1}{P_1}=\frac{1}{m}[T+U\sqrt{D}]$, $\frac{p_2}{P_2}=\frac{1}{m}[T-U\sqrt{D}]$, T and U denoting rational numbers, and m still representing the greatest common divisor of a, $2b$, c. These assumptions are legitimate, because $\frac{p_1}{P_1}$ and $\frac{p_2}{P_2}$ contain no irrationality but $\sqrt{D}$, and are conjugate with regard to $\sqrt{D}$. Substituting in the equations

$$\frac{P_1}{p_1}=\frac{Q_1}{q_1}=\frac{1}{m}(T+U\sqrt{D}),$$
$$\frac{P_2}{p_2}=\frac{Q_2}{q_2}=\frac{1}{m}(T-U\sqrt{D}),$$

for p_1, p_2; q_1, q_2; P_1, P_2; Q_1, Q_2; the expressions which these letters represent, and equating the rational and irrational parts, we find

$$\begin{vmatrix} \alpha, \beta \\ \gamma, \delta \end{vmatrix}=\frac{1}{m}\times\begin{vmatrix} T-bU, & -cU \\ aU, & T+bU \end{vmatrix}.$$

In this expression T and U satisfy the equation $T^2-DU^2=m^2$, because $p_1p_2=P_1P_2$. From this we infer that $\alpha\delta-\beta\gamma=1$; further, if we now introduce the condition that $\alpha, \beta, \gamma, \delta$ are to be integral and not merely rational numbers, it will follow, because $\gamma, \delta-\alpha, -\beta$ are integral, that $\frac{a}{m}U, \frac{2b}{m}U, \frac{c}{m}U$ are also integral; *i.e.* that U itself, and consequently T, is integral; so that the formula at which we have arrived coincides exactly with the formula (D). The system (2), treated in a similar manner, leads to the conclusion $\alpha\delta-\gamma\beta=-1$; whence it follows that that system can be satisfied by no proper automorphic of f.

This method, as Dirichlet observes, has the advantage of putting in a clear light the difference between proper and improper automorphism. A proper automorphic changes each of the two factors, into which the form may be decomposed, into a multiple of itself by a complex unit of the form $\frac{1}{m}[T+U\sqrt{D}]$; whereas improper automorphics, which only exist for particular kinds of forms, change each factor into a multiple of the other. A similar distinction subsists between proper and improper equivalence; the radical $\sqrt{D}$ entering with the same sign, or with opposite signs, into the factors which are transformed into one another, according as the transformation is proper or improper.

92. *Problem of Equivalence—Forms of a Negative Determinant.*—To complete the solution of the problem of equivalence, we consider, first, forms of a negative, and then those of a positive and not square determinant.

A form (a, b, c) of a negative determinant $D=-\Delta$, which satisfies the conditions enunciated in the following Table, is called a *reduced* form. The symbols $[2b]$ etc. are used to denote the absolute values of the quantities enclosed within the brackets.

General Conditions.	Special Conditions.
1. $[2b]\leqq[a]$.	1. If $a=c$, $b\geqq 0$.
2. $[2b]\leqq[c]$.	2. If $[2b]=[a]$, $b\geqq 0$.
3. $[a]\leqq[c]$.	

The essential character of a reduced form is sufficiently expressed by the two symmetrical conditions $[2b]\leqq[a]$, and $[2b]\leqq[c]$. The third general condition (which combined with the first implies the second), and the special conditions, are, it may be said, artificial restrictions, intended to enable us to enunciate with precision the theorem that "every class contains one, and only one, reduced form."

To show that one reduced form always exists in any given class, we select from the given class all those forms in which the coefficient of x^2 is the least; and again, from those forms we select that one form, (a, b, c), or those two forms, (a, b, c) and $(a, -b, c)$, in which the coefficient of y^2 is the least. The single form (a, b, c), or the two forms (a, b, c), $(a, -b, c)$, thus obtained, will, it is easy to see, satisfy the general conditions; and since, if $a=c$, or again if $[2b]=[a]$, the *opposite* forms (a, b, c) and $(a, -b, c)$, each of which satisfies the general conditions, are equivalent, and therefore both belong to the given class, it is clear that a form always exists satisfying the special conditions proper to these cases. That only one reduced form exists in each class may be proved by employing a principle due to Legendre (Théorie des Nombres, vol. i. p. 77).

"If $f=(a, b, c)$ be a form satisfying the general conditions for a reduced form, $f(1, 0)$ or a is the least number (other than zero) which can be represented by f; and $f(0, 1)$ or c is the least number which can be represented by f, with any value of the second indeterminate different from zero."

For, if we wish to find the least numbers that can be represented by f, it will be sufficient to attribute positive values to x and y in the formula $f=ax^2-2bxy+cy^2$, in which we suppose b positive as well as a and c. But

$$f(x-1, y)=f(x, y)-2b(x-y)-(a-2b)x-a(x-1),$$
$$f(x, y-1)=f(x, y)-2b(y-x)-(c-2b)y-c(y-1),$$

from which equations it appears that if in the formula $f(x, y)$ we diminish by a unit that indeterminate which is not less than the other, we diminish, or at least we do not increase, the value of $f(x, y)$, a conclusion which leads immediately to the principle enunciated by Legendre.

From this principle it follows that a form satisfying the general conditions of reduction is the form, or one of the two opposite forms, to which we are led by the process of selection above described. If, therefore, there be two reduced forms in the same class, they must be two opposite forms (a, b, c) and $(a, -b, c)$. But it is easily proved that two such opposite forms, each satisfying the general conditions of reduction, cannot be equivalent, unless either $[2b]=a$, or $a=c$; in which cases only one of the two forms satisfies the special conditions. In every case, therefore, there exists one, and only one, reduced form in each class.

To obtain the reduced form equivalent to a given form, we form a series of *contiguous* forms, beginning with the given form and ending with the reduced form (Disq. Arith. art. 171). Two forms of the same determinant, (a, b, c) and (a', b', c'), are said to be *contiguous* when $c=a'$, and $b+b'\equiv 0$, mod a'. Two contiguous forms are always equivalent; for if $b+b'=\mu a'$, the former passes into the latter by the transformation $\begin{vmatrix} 0, & -1 \\ 1, & \mu \end{vmatrix}$.

Let, then, (a_0, b_0, a_1) be the given form of det. $-\Delta$, which is supposed not to satisfy the general conditions for a reduced form. Let $b_0+b_1=\mu_1 a_1$, $-b_1$ denoting the *minimum* residue of b_0, mod a_1, so that $[2b_1]\leqq a_1$; and let a_2 represent the integral number $\frac{b_1^2+\Delta}{a_1}$. The form (a_1, b_1, a_2) will be contiguous, and therefore equivalent, to (a_0, b_0, a_1). Let a third form, (a_2, b_2, a_3), be similarly derived from (a_1, b_1, a_2), and let the series of contiguous forms (a_0, b_0, a_1), (a_1, b_1, a_2), (a_2, b_2, a_3), ... be continued until we arrive at a form (a_n, b_n, a_{n+1}), in which $a_{n+1}\geqq a_n$. We shall certainly arrive at such a form, or we should have a series of numbers $a_1, a_2, a_3, \ldots$ all represented by the form (a_0, b_0, a_1), and yet continually decreasing for ever; whereas a form of negative determinant can acquire only a finite number of values inferior to any given limit. The form (a_n, b_n, a_{n+1}), in which $a_n\leqq a_{n+1}$, satisfies the general conditions for a reduced form. For by the law of the series of forms $[2b_n]\leqq a_n$; and since $a_n\leqq a_{n+1}$, we have also

$$[2b_n]\leqq a_{n+1}.$$

Again, the process can always be terminated in such a manner as to give a form satisfying the special conditions for a reduced form. If $a_n=a_{n+1}$, and b_n is negative, instead of stopping at the form (a_n, b_n, a_n), we continue the process one step further and obtain the reduced form $(a_n, -b_n, a_n)$. If $-2b_n=a_n$, instead of the form (a_n, b_n, a_{n+1}), we take the form $(a_n, -b_n, a_{n+1})$, which is contiguous to (a_{n-1}, b_{n-1}, a_n), for the concluding form of the series.

The transformation $|T_n|$ by which (a_0, b_0, a_1) passes into the equivalent reduced form (a_n, b_n, a_{n+1}), is

$$\begin{vmatrix} 0, & -1 \\ 1, & \mu_1 \end{vmatrix} \times \begin{vmatrix} 0, & -1 \\ 1, & \mu_2 \end{vmatrix} \times \ldots\ldots\ldots\ldots \times \begin{vmatrix} 0, & -1 \\ 1, & \mu_n \end{vmatrix},$$

where

$$\mu_i=\frac{b_{i-1}+b_i}{a_i};$$

or if we represent the successive convergents to the continued fraction

$$-\cfrac{1}{\mu_1-\cfrac{1}{\mu_2-\cfrac{1}{\mu_3-\cfrac{1}{\mu_4}-\ldots}}}$$

by $\frac{P_0}{Q_0}, \frac{P_1}{Q_1}, \frac{P_2}{Q_2}, \ldots$, so that $P_0=0$, $P_1=-1$, $P_2=-\mu_2, \ldots$, $Q_0=1$, $Q_1=\mu_1$, $Q_2=\mu_1\mu_2-1, \ldots$, we may express $|T_n|$ by the formula

$$|T_n|=\begin{vmatrix} P_{n-1}, & P_n \\ Q_{n-1}, & Q_n \end{vmatrix}.$$

The theory of the reduction of quadratic forms was first given by Lagrange. (See his 'Recherches d'Arithmétique' in the Nouveaux Mémoires de l'Académie de Berlin for 1773; see also his Additions to Euler's Algebra, art. 32; a memoir of Euler's, "De insigni promotione scientiæ numerorum," Opusc. Anal. vol. ii. p. 273, or Comment. Arith. vol. ii. p. 140; Legendre, Théorie des Nombres, première partie, sect. viii.; Disq. Arith. arts. 171–173; M. Hermite in Crelle's Journal, vol. xli. p. 193.) The method is applicable to forms of a positive, as well as to those of a negative determinant; but when the determinant is positive, the reduced forms are not, in general, all non-equivalent. When the determinant is negative, it is as applicable to forms, of which the coefficients are any real quantities whatever, as to those of which the coefficients are integral numbers. We shall revert hereafter to the consequences which M. Hermite has deduced from this important observation.

We have now a complete solution of the problem of equivalence for forms of a negative determinant. To decide whether two forms f_1 and f_2 of the same negative determinant are equivalent or not, we have only to investigate the reduced forms ϕ_1 and ϕ_2 equivalent to f_1 and f_2: according as ϕ_1 and ϕ_2 are or are not identical, f_1 and f_2 are or are not equivalent; and if they are equivalent, all the transformations of f_1 into f_2 are obtained, by compounding the reducing transformation of f_1, first, with the automorphics of ϕ_2, and then with the inverse of the reducing transformation of f_2.

93. *Problem of Equivalence for Forms of a Positive and not Square Determinant.*—The solution of the problem of equivalence for forms of a positive and not square determinant occupies a considerable space in the Disq. Arith. (arts. 183–196). But, as Lejeune Dirichlet has observed, in a memoir which he has devoted to this problem ("Vereinfachung der Theorie der binären quadratischen Formen," in the Memoirs of the Academy of Berlin for 1854, or in Liouville, New Series, vol. ii. p. 353), the demonstrations relating to it may be greatly abbreviated by employing certain known results of the theory of continued fractions. The following method does not differ materially from that proposed by Lejeune Dirichlet; nor indeed is it, in principle, very distinct from that of Gauss, the connexion of which with the theory of continued fractions he has suppressed.

We shall suppose that the forms which we consider are primitive—a supposition which involves no loss of generality; and we shall understand, in what follows, by a "quadratic equation," an equation of the form

$$a_0+2b_0\theta+a_1\theta^2=0,$$

in which $b_0^2-a_0 a_1$ is positive, and a_0, b_0, a_1 are integral numbers without any common divisor. Such a quadratic equation we shall symbolize by the formula $[a_0, b_0, a_1]$, and we shall regard the two quadratic equations $[a_0, b_0, a_1]$, $[-a_0, -b_0, -a_1]$ as different. If $\sqrt{D}$ denote the positive square root of $b_0^2-a_0 a_1$, it is convenient to call

$$\frac{-b_0-\sqrt{D}}{a_1}, \text{ and } \frac{-b_0+\sqrt{D}}{a_1}$$

the first and second roots of $[a_0, b_0, a_1]$ respectively; so that if we change the sign of the equation throughout, we change at the same time the denomination of the roots. Whenever therefore a root of a quadratic equation, and the denomination of the root, are given, the quadratic equation itself is given. It is readily seen that if two forms (a_0, b_0, a_1), (A_0, B_0, A_1) be properly or improperly equivalent, so that $\begin{vmatrix} \alpha, \beta \\ \gamma, \delta \end{vmatrix}$ transforms (a_0, b_0, a_1) into

(A_0, B_0, A_1), the *corresponding* roots of the quadratics

$$a_0+2b_0\omega+a_1\omega^2=0,\ A_0+2B_0\Omega+A_1\Omega^2=0,$$

i.e. those which are connected by the relation $\omega=\frac{\gamma+\delta\Omega}{\alpha+\beta\Omega}$, are of the same, or of opposite, denominations, according as the equivalence is proper or improper. Let the first root of the equation $[a_0, b_0, a_1]$ be developed in a continued fraction, of which all the integral quotients are positive except the first, which has the same sign as the root. In this process we obtain a perfectly determinate series of transformed equations, each having a complete quotient of the development for its first or second root, according as it occupies an uneven or an even place in the series, counting from the proposed equation inclusive. The complete quotients eventually form a period of an even number of terms; there exists therefore a corresponding period of transformed quadratic equations, which will be of the type

$$[\alpha_0, \beta_0, \alpha_1],\ [\alpha_1, \beta_1, \alpha_2],\ [\alpha_2, \beta_2, \alpha_3], \ldots\ldots [\alpha_{2k-1}, \beta_{2k-1}, \alpha_0].$$

Every equation of the period has one of its roots positive and greater than unity, the other negative and less in absolute magnitude than unity; and if we suppose (as we shall do) that we begin the period with an equation occupying an uneven place in the series of transformed equations, the positive root of any equation of the period will be its first or second root, according as it occupies an uneven or an even place in the period.

To apply what has preceded to our present problem, we require the following lemma (see sect. 2 of Dirichlet's memoir, or M. Serret in Liouville, vol. xv. p. 153).

"If ω and Ω be two irrational quantities connected by the relation $\omega=\frac{\gamma+\delta\Omega}{\alpha+\beta\Omega}$, where $\alpha, \beta, \gamma, \delta$ are integral and $\alpha\delta-\beta\gamma=\pm1$, the developments of ω and Ω in a continued fraction will ultimately coincide, and the same quotient will occupy an even or an uneven place in both developments alike, if $\alpha\delta-\beta\gamma=+1$, but an even place in the one, and an uneven place in the other, if $\alpha\delta-\beta\gamma=-1$."

A quadratic form $(\alpha_0, \beta_0, \alpha_1)$ of positive determinant, is said to be *reduced** when the roots of $[\alpha_0, \beta_0, \alpha_1]$ are of opposite signs; the absolute value of the first root being greater, that of the second less than unity. A series of reduced forms equivalent to any proposed form (a_0, b_0, a_1) can always be found. For, if the first root of $[a_0, b_0, a_1]$ be developed in a continued fraction, and if its period of equations (beginning with an equation occupying an uneven place in the series of transformed equations) be represented as before by $[\alpha_0, \beta_0, \alpha_1]$, $[\alpha_1, \beta_1, \alpha_2]$, ... $[\alpha_{2k-1}, \beta_{2k-1}, \alpha_0]$, the forms $(\alpha_0, \beta_0, \alpha_1), (\alpha_1, -\beta_1, \alpha_2), \ldots\ldots (\alpha_{2k-1}, -\beta_{2k-1}, \alpha_0)$ will be all reduced and all equivalent to (a_0, b_0, a_1). These forms, so deduced from the development of the first root of the equation $[a_0, b_0, a_1]$, we shall term the period of forms equivalent to (a_0, b_0, a_1), or, more briefly, the period of (a_0, b_0, a_1). It will be seen that each form of the period is contiguous to that which precedes it, and that the first is contiguous to the last.

We can now obtain a complete solution of our problem. If (a_0, b_0, a_1) and (A_0, B_0, A_1) are equivalent, the first roots of $[a_0, b_0, a_1]$ and $[A_0, B_0, A_1]$ will be corresponding roots, and the developments of these two roots will ultimately coincide, giving one and the same period of complete quotients.

* These reduced forms are not to be confounded with the reduced forms of the last article.

And, since the same complete quotient will occur in an even or in an uneven place alike in each development, it will be a root of the same denomination in the quadratic equation determining it in each development. The period of equations will therefore be precisely the same for each development; and the same equation may be taken as the first equation of each period. Consequently the periods of (a_0, b_0, a_1), (A_0, B_0, A_1) are identical. Two forms therefore are or are not equivalent, according as their periods are or are not identical. To obtain the transformations of (a_0, b_0, a_1) into (A_0, B_0, A_1), when these two forms are equivalent, let the complete quotients in the development of the first root of $[a_0, b_0, a_1]$ be $\omega_1, \omega_2 \ldots\ldots$, and let the convergent immediately preceding ω_{n+1} be $\frac{q_n}{p_n}$. Similarly, let Ω_{n+1} and $\frac{Q_n}{P_n}$ be a complete quotient and a convergent in the development of the first root of $[A_0, B_0, A_1]$. Then, if $\omega_\mu = \Omega_M$ (where $\mu \equiv M$, mod 2), all the transformations of (a_0, b_0, a_1) into (A_0, B_0, A_1) are comprised in the formula

$$\left|\begin{matrix} p_{\mu-1}, p_\mu \\ q_{\mu-1}, q_\mu \end{matrix}\right| \times |T| \times \left|\begin{matrix} P_{M-1}, P_M \\ Q_{M-1}, Q_M \end{matrix}\right|^{-1},$$

$|T|$ denoting any automorphic of the form corresponding to the equation of which $\omega_{\mu+1}$ or Ω_{M+1} is a root.

It should be observed that a reduced form is always a form of its own period. To prove this, we remark that reduced forms are of two kinds; they are either such as $(\alpha_0, \beta_0, \alpha_1)$, where the first root of $[\alpha_0, \beta_0, \alpha_1]$ is positive, or such as $(\alpha_1, -\beta_1, \alpha_2)$, where the first root of $[\alpha_1, -\beta_1, \alpha_2]$ is negative. Now a reduced form such as $(\alpha_0, \beta_0, \alpha_1)$ is evidently a form of its own period, for the equation $[\alpha_0, \beta_0, \alpha_1]$ is itself an equation of the period in the development of its first root. And a reduced form such as $(\alpha_1, -\beta_1, \alpha_2)$ is also a form of its own period. For if we develope the second root of $[\alpha_1, \beta_1, \alpha_2]$, we obtain a period of equations of which $[\alpha_1, \beta_1, \alpha_2]$ is itself one. Let $[\alpha_2, \beta_2, \alpha_3]$ be the equation immediately following $[\alpha_1, \beta_1, \alpha_2]$ in this period; then $[\alpha_1, \beta_1, \alpha_2]$ is an equation occupying an even place in the period of equations arising from the development of the first root of $[\alpha_2, \beta_2, \alpha_3]$, and consequently $(\alpha_1, -\beta_1, \alpha_2)$ is a form in the period of $(\alpha_2, \beta_2, \alpha_3)$; *i.e.* it is a form in its own period, because it is equivalent to $(\alpha_2, \beta_2, \alpha_3)$.

It follows from this that no reduced form can be equivalent to a given form, unless it occur in the period of that form.

The inequalities satisfied by the roots of any equation of a period give rise to certain inequalities which are satisfied by its coefficients. These inequalities (which are not all independent) are,

(i) $[\alpha_0] < 2\sqrt{D}$; $[\beta_0] < \sqrt{D}$; $[\alpha_1] < 2\sqrt{D}$.

(ii) $\sqrt{D} - [\beta_0] < [\alpha_0] < \sqrt{D} + [\beta_0]$;

(iii) $\sqrt{D} - [\beta_0] < [\alpha_1] < \sqrt{D} + [\beta_0]$.

The same inequalities are, of course, satisfied by the coefficients of a reduced form; its middle coefficient is, moreover, positive. And conversely, every form whose middle coefficient is positive and whose coefficients satisfy these inequalities is a reduced form.

94. *Improper Equivalence—Ambiguous Forms and Classes.*—If it be required to find whether two forms (a, b, c) and (a', b', c') of the same positive

or negative determinant are or are not improperly equivalent, it will suffice to change one of them, as (a, b, c), into its opposite $(a, -b, c)$, and then to solve the problem of proper equivalence for $(a, -b, c)$ and (a', b', c'). If it be found that these two forms are properly equivalent, let $|T|$ represent any transformation of the first into the second; then the improper transformations of (a, b, c) into (a', b', c') will be represented by the formula $\begin{vmatrix} 1, & 0 \\ 0, & -1 \end{vmatrix} \times |T|$.

It may happen that two forms are both properly and improperly equivalent to one another; when this is the case, each of the two forms, and every form of the class to which they belong, is improperly equivalent to itself, *i.e.* admits of improper automorphics. A class consisting of such forms is said to be ambiguous (*classis anceps—classe ambigüe*). An *ambiguous form* is a form (a, b, c) in which $2b$ is divisible by a; if $2b = \mu a$, the ambiguous form is transformed into itself by the improper automorphic $\begin{vmatrix} 1, & \mu \\ 0, & -1 \end{vmatrix}$; and if $|T|$ be the general expression of its proper automorphics, all its improper automorphics are included by the formula $\begin{vmatrix} 1, & \mu \\ 0, & -1 \end{vmatrix} \times |T|$. Every ambiguous form belongs to an ambiguous class, and, as we shall presently see, every ambiguous class contains ambiguous forms.

To complete the theory of equivalence, we shall here briefly indicate the solution of the problem, "To decide whether a given form is improperly equivalent to itself or not, and if it is, to find its improper automorphics."

When the determinant is negative, it follows from the principle that two reduced forms cannot be equivalent, that no reduced form, the opposite of which is different from it and is also a reduced form, can be improperly equivalent to itself. Hence the only reduced forms which have improper automorphics are those in which $b=0$, or $2b=a$, or $a=c$. In the two former cases the reduced form is ambiguous, in the latter it has the improper automorphic $\begin{vmatrix} 0, & 1 \\ 1, & 0 \end{vmatrix}$, and is moreover contiguous and therefore equivalent to the ambiguous form $(2a-2b, a-b, a)$. These considerations supply a sufficient criterion for deciding whether a form of negative determinant is equivalent to itself or not. If it is, its improper automorphics are given by the formula $|T| \times |\tau| \times |T|^{-1}$; $|T|$ denoting the reducing transformation of the given form, and $|\tau|$ any improper automorphic of the reduced form. For forms of a positive determinant, we observe that if $(\alpha_0, \beta_0, \alpha_1), (\alpha_1, -\beta_1, \alpha_2), \ldots \ldots (\alpha_{2k-1}, -\beta_{2k-1}, \alpha_0)$ be the period of (a, b, c), the period of $(a, -b, c)$ is $(\alpha_0, -\beta_{2k-1}, \alpha_{2k-1}), (\alpha_{2k-1}, \beta_{2k-2}, \alpha_{2k-2}), \ldots \ldots (\alpha_1, \beta_0, \alpha_0)$. For $(a, -b, c)$ is equivalent to $(\alpha_0, -\beta_{2k-1}, \alpha_{2k-1})$, because (a, b, c) is equivalent to $(\alpha_{2k-1}, -\beta_{2k-1}, \alpha_0)$; and by a known theorem, the period of equations in the development of the second root of (a, b, c) is $[\alpha_0, -\beta_{2k-1}, \alpha_{2k-1}]$, $[\alpha_{2k-1}, -\beta_{2k-2}, \alpha_{2k-2}], \ldots \ldots [\alpha_1, -\beta_0, \alpha_0]$, the equation $[\alpha_0, -\beta_{2k-1}, \alpha_{2k-1}]$ occupying an even place in the development; this period is therefore the period of equations in the development of the first root of $[\alpha_0, -\beta_{2k-1}, \alpha_{2k-1}]$; *i.e.* the period $(\alpha_0, -\beta_{2k-1}, \alpha_{2k-1}), (\alpha_{2k-1}, \beta_{2k-2}, \alpha_{2k-2}), \ldots (\alpha_1, \beta_0, \alpha_0)$ is the period of $(\alpha_0, -\beta_{2k-1}, \alpha_{2k-1})$, or, which is the same thing, of $(a, -b, c)$. If we now suppose that (a, b, c) is improperly equivalent to itself, it will be properly equivalent to $(a, -b, c)$; and these two forms will have the same period, which we shall represent by $(p_0, q_0, p_1), (p_1, q_1, p_2)$, &c. If $(p_\lambda, q_\lambda, p_{\lambda+1})$ be any form of this period, the *associate* of $(p_\lambda, q_\lambda, p_{\lambda+1})$, *i. e.* the form $(p_{\lambda+1}, q_\lambda, p_\lambda)$, will also be a form of the period, and the indices of these two forms in the period will differ by an uneven number, because the signs of the numbers $p_\lambda, p_{\lambda+1}, \ldots$ are alternate. From this we can infer that there will be two different forms in the period, each of which will be immediately preceded by its own associate; so that the type of the period will be

$$(p_0, q_0, p_1), (p_1, q_1, p_2), \ldots . (p_{k-1}, q_{k-1}, p_k),$$
$$(p_k, q_{k-1}, p_{k-1}), (p_{k-1}, q_{k-2}, p_{k-2}), \ldots (p_1, q_0, p_0),$$

where for simplicity we have supposed that (p_0, q_0, p_1) is one of the two forms which is preceded by its associate; the other is (p_k, q_{k-1}, p_{k-1}). These two forms are ambiguous, for it follows from the contiguity of each form to that which precedes it, that $2q_0 \equiv 0$, mod p_0; $2q_{k-1} \equiv 0$, mod p_k. We arrive therefore at the conclusion that the period of every ambiguous class contains two ambiguous forms; either of which enables us, as in the case of forms of a negative determinant, to obtain all the improper automorphics of any form of the class.

Gauss has shown (Disq. Arith. art. 164), by an analysis which it is not necessary to explain here, that if f contain F both properly and improperly, an ambiguous form contained in f, and containing F, can always be assigned. This theorem comprehends the result which we have incidentally obtained in this article, that every ambiguous class contains ambiguous forms. (See also a note by Dirichlet, in Liouville, New Series, vol. ii. p. 273.)

95. The important theorem, that for every positive or negative determinant the number of classes is finite, is a consequence of the theory of reduction. To establish its truth, it is sufficient to employ the reduction of Lagrange (art. 92), which is applicable to forms of a positive determinant having integral coefficients no less than to forms of a negative determinant, and which shows that in every class of forms of determinant D there exists one form at least the coefficients of which satisfy the inequalities $[2b] \leqq [a]$, $[2b] \leqq [c]$. These inequalities give, if D be negative, $ac \leqq -\frac{4}{3}D$, $[b] \leqq \sqrt{-\frac{D}{3}}$; and if D be positive, $[ac] \leqq D$, $[b] \leqq \sqrt{\frac{D}{5}}$. The number of forms whose coefficients satisfy these inequalities is evidently limited; therefore, *à fortiori*, the number of non-equivalent classes is finite.

To construct a system of representative forms of det. D, we have only to write down all the forms of det. D whose coefficients satisfy the preceding inequalities, to which we may add $[a] \leqq [c]$. If the determinant be negative, it only remains to reject the forms which do not satisfy the special conditions; if it be positive, we must examine whether any of the forms which we have written down are equivalent; and, if so, retaining only one form out of each group of equivalent forms, we shall have the representative system required.

A few particular cases of the theory merit attention from their simplicity. If $D = -1$, there is but one class of forms, represented by x^2+y^2; and by the theorems of arts. 87 and 90, the number of representations of any uneven (or unevenly even) number by the form x^2+y^2 is the quadruple of the excess of the number of its divisors of the form $4n+1$, above the number of its divisors of the form $4n+3$. (See Jacobi in Crelle's Journal, vol. xii. p. 169; Dirichlet, *ibid.* vol. xxi. p. 3. In counting the solutions of the equation

$x^2+y^2=2p$, Jacobi considers two solutions, such as $x_1^2+y_1^2=2p$ and $x_2^2+y_2^2=2p$, to be identical, when $x_1^2=x_2^2$, $y_1^2=y_2^2$; the number of solutions is thus a fourth part of the number of representations.) In particular every prime of the form $4n+1$ (and the double of every such prime) is capable of decomposition in one way, and one only, into two squares relatively prime; and, conversely, every uneven number capable of such decomposition in one way only is a prime of the form $4n+1$.

If $D=-2$, x^2+2y^2 represents the only class of forms; and every uneven number can be represented by x^2+2y^2, in twice as many ways as it has divisors of either of the forms $8n+1$, or $8n+3$, in excess of divisors of the forms $8n+5$, or $8n+7$. (Dirichlet, *loc. cit.*) In particular every prime of either of the forms $8n+1$ or $8n+3$ is decomposable in one way, and in one only, into a square and the double of a square.

Again, for each of the determinants -3 and -7, there is but one properly and one improperly primitive class, which may be represented by the forms $(1, 0, 3)$ and $(2, 1, 2)$; $(1, 0, 7)$ and $(2, 1, 4)$. Uneven numbers are therefore represented by x^2+3y^2, in twice as many ways as they have divisors of the form $3n+1$, in excess of divisors of the form $3n-1$; and by x^2+7y^2 in twice as many ways as they have divisors of the forms $7n+1, 2, 4$, in excess of divisors of the forms $7n+3, 5, 6$. Similarly, x^2+4y^2 represents the only primitive class of det. -4.

For each of the eleven positive determinants of the first century 2, 5, 13, 17, 29, 41, 53, 61, 73, 89, 97, there is but one properly primitive class; there is also for the ten uneven determinants one improperly primitive class. Representing any one of these eleven numbers by D, by $[T, U]$ the least solution of $T^2-DU^2=1$, and by M an uneven positive number prime to D we may enunciate the theorem,

"The equation $x^2-Dy^2=M$ is capable of as many solutions in positive numbers x and y, satisfying the conditions $x \leqq T\sqrt{M}$, $y \leqq U\sqrt{M}$, as M has divisors of which D is a quadratic residue in excess of divisors of which D is a quadratic non-residue."

Thus the number of solutions of the equation $x^2-2y^2=M$, where M is an uneven number, and $0<x\leqq 3\sqrt{M}$, $0<y\leqq 2\sqrt{M}$, is the excess of the divisors of M of the forms $8n\pm1$ above its divisors of the forms $8n\pm3$.

The conditions $0<x\leqq T\sqrt{M}$, $0<y\leqq U\sqrt{M}$, which are satisfied by one representation, and only one, in each set, are obtained by considerations to which we shall hereafter refer (art. 100).

96. *The Pellian Equation.*—The two indeterminate equations, $T^2-DU^2=1$ and $T^2-DU^2=4$, are, as we have seen, of primary importance in the theory of quadratic forms of a positive and not square determinant. When the complete solution of these equations is known, we can deduce, from a single representation of a number by a form, every representation of the same set; and, from a single transformation of either of two equivalent forms into the other, every similar transformation. The same equations also present themselves in the solution in integral numbers of the general equation of the second degree containing two indeterminates, and enable us in the principal case in which it admits an infinite number of solutions to deduce them all from a certain finite number. This fundamental importance of the equation $T^2-DU^2=1$ was first recognized by Euler, who has left several memoirs relating to it (see Comment. Arith., vol. i. pp. 4, 316; vol. ii. p. 35; also Euler's Algebra, vol. ii. cap. vii.); but the equation itself had already given rise to a discussion which forms a well-known passage in the scientific history of the seventeenth century. Its solution was proposed by Fermat (see the

Commercium Epistolicum of Wallis, Ep. 8) as a challenge to the English mathematicians, and especially to Wallis. The problem was at first misunderstood by Lord Brouncker and Wallis, who each gave a method for its solution in fractional numbers; not attending to the restriction to integral numbers implied, though not expressed, in Fermat's enunciation, without which the problem is of a very elementary character. Ultimately, however, they obtained a complete solution by a method, which Wallis describes in the Comm. Epist. Epp. 17 (postscript) and 19, and in his Algebra, capp. xcviii. and xcix., attributing it to Lord Brouncker, though he seems himself to have had some share in its invention. This method is the same as that which is given by Euler in his Algebra, and in the first of the memoirs above cited, and which is attributed by him to Pell *. It differs, in form at least, from that now employed, and was evidently suggested by the artifices of substitution employed in Diophantine problems. It is most easily explained by an example. If $T^2-13U^2=1$ be the equation proposed, the process would stand thus:—

(1) $3U<T<4U$; let $T=3U+v_1$; $-4U^2+6Uv_1+v_1^2=1$,

(2) $v_1<U<2v_1$; let $U=v_1+v_2$; $3v_1^2-2v_1v_2-4v_2^2=1$,

(3) $v_2<v_1<2v_2$; let $v_1=v_2+v_3$; $-3v_2^2+4v_2v_3+3v_3^2=1$,

(4) $v_3<v_2<2v_3$; let $v_2=v_3+v_4$; $4v_3^2-2v_3v_4-3v_4^2=1$,

(5) $v_4<v_3<2v_4$; let $v_3=v_4+v_5$; $-v_4^2+6v_4v_5+4v_5^2=1$,

(6) $6v_5<v_4<7v_5$; let $v_4=6v_5+v_6$; $4v_5^2-6v_5v_6-v_6^2=1$,

(7) $v_6<v_5<2v_6$; let $v_5=v_6+v_7$; $-3v_6^2+2v_6v_7+4v_7^2=1$,

(8) $v_7<v_6<2v_7$; let $v_6=v_7+v_8$; $3v_7^2-4v_7v_8-3v_8^2=1$,

(9) $v_8<v_7<2v_9$; let $v_7=v_8+v_9$; $-4v_8^2+2v_8v_9+3v_9^2=1$,

(10) $v_9<v_8<2v_9$; let $v_8=v_9+v_{10}$; $v_9^2-6v_9v_{10}-4v_{10}^2=1$.

In the last equation we may put $v_9=1$, $v_{10}=0$; whence $T=649$, $U=180$. It will be seen that the success of the method depends on its leading at last to an equation in which the coefficient of one of the indeterminates is $+1$. Wallis does not prove that such an equation will always occur; and the demonstration which he has given of the resolubility of the equation $T^2-DU^2=1$ is inconclusive. (See his Algebra, cap. xcix.; the reader will find the paralogism which vitiates his reasoning in the proof of the lemma, upon which it depends; see also Lagrange's criticism in the 8th paragraph of the Additions to Euler's Algebra; and Gauss, Disq. Arith. art. 202, note.) It is evident that the method of solution employed by Wallis really consists in the successive determination of the integral quotients in the development of $\frac{T}{U}$ in a continued fraction; in addition to this, Euler observed that $\frac{T}{U}$ is itself necessarily a convergent to the value of $\sqrt{D}$; so that to obtain the numbers T and U it suffices to develope $\sqrt{D}$ in a continued fraction. It is singular, however, that it never seems to have occurred to him that, to complete the theory of the problem, it was necessary to demonstrate that the equation is always resoluble, and that all its solutions are given by the development of $\sqrt{D}$. His memoir (Comment. Arith. vol. i. p. 316) contains all the elements necessary

* There does not seem to be any ground for attributing either the problem or its solution to Pell; and it is possible that Euler may have been misled by a confused recollection of the contents of Wallis's Algebra, in which an account is given of the method employed by Pell in solving Diophantine problems. Nevertheless the equation $T^2-DU^2=1$ is often called the Pellian equation after him, probably upon Euler's authority.

to the demonstration, but here, as in some other instances, Euler is satisfied with an induction which does not amount to a rigorous proof. The first admissible proof of the resolubility of the equation was given by Lagrange in the Mélanges de la Société de Turin, vol. iv. p. 41. He there shows that in the development of $\sqrt{D}$, we shall obtain an infinite number of solutions of some equation of the form $T^2-DU^2=A$, and that, by multiplying together a sufficient number of these equations, we can deduce solutions of the equation $T^2-DU^2=1$. But the simpler demonstration of its solubility, which is now to be found in most books on algebra, and which depends on the completion of the theory (left unfinished by Euler) of the development of a quadratic surd in a continued fraction, was first given by Lagrange in the Hist. de l'Académie de Berlin for 1767 and 1768, vol. xxiii. p. 272, vol. xxiv. p. 236; and, in a simpler form, in the Additions to Euler's Algebra, art. 37. Lastly, Gauss, who in the Disq. Arith. avoids the use of continued fractions, has shown that if we form by the method which he indicates, the period of any quadratic form of det. D, we may infer the complete solution of the equation $T^2-DU^2=1$, or $=4$, from the automorphics of any reduced form, according as the form is properly or improperly primitive. (Disq. Arith. art. 198–202.)

To express conveniently the principal theorems relating to these equations, we employ the following notation *. The numerator of the continued fraction

$$q_1+\frac{1}{q_2}+\frac{1}{q_3}+\ldots+\frac{1}{q_n}$$

is called the *cumulant* of the numbers $q_1, q_2, \ldots q_n$, and is represented by the symbol $(q_1, q_2, q_3, \ldots q_n)$; the denominator is evidently the cumulant $(q_2, q_3, \ldots q_n)$. Accents are sometimes employed to indicate that the first or last quotient of a cumulant is to be omitted; thus $'(q_1, q_2, q_3, \ldots q_n) =(q_2, q_3, \ldots q_n)$, $(q_1, q_2, q_3, \ldots q_n)'=(q_1, q_2, q_3, \ldots q_{n-1})$, $'(q_1, q_2, \ldots q_n)' =(q_2, q_3, \ldots q_{n-1})$. A *periodic* cumulant is represented by the notation $(\dot{q}_1, q_2, \ldots \dot{q}_n)_x$, the suffix indicating the number of times which the period is repeated, and a point being placed over the first and last quotients of the period. In what follows m represents 1 or 2, according as we are considering the equation $T^2-DU^2=1$, or $=4$.

(i.) If $\mu_1, \mu_2, \ldots \mu_{2k}$ be the period of integral quotients in the development of either root of a quadratic equation of determinant D, which we suppose properly or improperly primitive according as $m=1$, or $m=2$, the positive numbers T_x and U_x which satisfy the equation $T^2-DU^2=m^2$, are all contained in the formulæ

$$\frac{T_x}{m}=\frac{1}{2}(A_x+\Delta_x),$$

$$\frac{U_x}{m}=\frac{B_x}{-\alpha_0}=\frac{A_x-\Delta_x}{-2\beta_0}=\frac{\Gamma_x}{\alpha_1};$$

where

$$A_x=(\dot{\mu}_1, \mu_2, \ldots \dot{\mu}_{2k})_x, \qquad B_x=(\dot{\mu}_1, \mu_2, \ldots \dot{\mu}_{2k})_x',$$

$$\Gamma_x='(\dot{\mu}_1, \mu_2, \ldots \dot{\mu}_{2k})_x, \qquad \Delta_x='(\dot{\mu}_1, \mu_2, \ldots \dot{\mu}_{2k})_x',$$

* This notation is due to Euler (see Nov. Comm. Pet. vol. ix. p. 53, and the memoir already cited, "De usu novi algorithmi in Problemate Pelliano solvendo." Comment. Arith. vol. i. p. 316). The convenient term "cumulant" has been introduced by Professor Sylvester (Phil. Trans. vol. cxliii. p. 474), who has also suggested the use of accents to indicate the omission of initial or final quotients.

and $\alpha_0+2\beta_0\theta+\alpha_1\theta^2=0$ is the quadratic equation determining the quotient μ_1, in which we suppose for simplicity that α_1 is positive.

If, in particular, we consider the quadratic equation $\theta^2-D=0$, or rather $a^2-D-2a\theta+\theta^2=0$, where $a^2<D<(a+1)^2$, we have $m=1$, $\mu_1=2a$, and we find, by the symmetry of the period in this case,

$$T_x=\tfrac{1}{2}(A_x+\Delta_x)=(a, \mu_2, \mu_3, \ldots \mu_{2k}, \dot{2a}, \mu_2, \ldots \dot{\mu}_{2k})_{x-1},$$

$$U_x=(\mu_2, \mu_3, \ldots \mu_{2k}, \dot{2a}, \mu_2, \ldots \dot{\mu}_{2k})_{x-1},$$

which are Euler's formulæ for the solution of the equation $T^2-DU^2=1$.

(ii.) We have already observed (art. 90) that when T_1 and U_1 are known, T_x and U_x are defined by the equation

$$\frac{T_x+U_x\sqrt{D}}{m}=\left[\frac{T_1+U_1\sqrt{D}}{m}\right]^x.$$

Either from this equation, or from the cumulantive formulæ for T_x, U_x, we infer that T_x and U_x satisfy the equation of finite differences,

$$v_{x+2}-\frac{2T_1}{m}v_{x+1}+v_x=0;$$

so that the two series, of which T_x and U_x are the general terms, are each a recurring series, the scale of relation being $1, -\frac{2T_1}{m}, 1$.

It is convenient to observe that $T_{-x}=T_x$; but $U_{-x}=-U_x$.

(iii.) If we denote by ψ the imaginary arc

$$\frac{1}{i}\log\left(\frac{T_1+U_1\sqrt{D}}{m}\right),$$

we have evidently $\frac{T_1}{m}=\cos\psi$, $\frac{U_1\sqrt{D}}{mi}=\sin\psi$, $\frac{T_x}{m}=\cos x\psi$, $\frac{U_x\sqrt{D}}{mi}=\sin x\psi$.

The analogy implied by these formulæ enables us to transform many trigonometrical identities into formulæ containing T_x and U_x. For example, from the formulæ $\cos(\phi\pm\theta)=\cos\phi\cos\theta\mp\sin\phi\sin\theta$, $\sin(\phi\pm\theta)=\sin\phi\cos\theta\pm\sin\theta\cos\phi$, we have, putting $\phi=x\psi$, $\theta=y\psi$, where x and y are any positive or negative integers,

$$T_{x\pm y}=\frac{1}{m}[T_x T_y\pm DU_x U_y],$$

$$U_{x\pm y}=\frac{1}{m}[T_x U_y\pm T_y U_x].$$

(iv.) It is also found that

$$\frac{T_x}{m}=(-1)^{\frac{x(x-1)}{2}}\left(\frac{T_1}{m}, -\frac{2T_1}{m}, \frac{2T_1}{m}, \ldots (-1)^{x-1}\frac{2T_1}{m}\right),$$

$$\frac{U_x}{U_1}=(-1)^{\frac{1}{2}(x-1)(x-2)}\left(\frac{2T_1}{m}, -\frac{2T_1}{m}, \ldots (-1)^{x-1}\frac{2T_1}{m}\right).$$

(v.) If q be any integral number whatever, we can always find a solution $[T_\lambda, U_\lambda]$ satisfying the congruences $T_\lambda\equiv T_0=m$, mod q, and $U_\lambda\equiv U_0=0$, mod q. If $[T_\lambda, U_\lambda]$ be the least solution satisfying these congruences, λ will be less than $2q$, and the residues (mod q) of the terms of the two series T_x and U_x will each form a period of λ terms, so that we shall always have $T_{x+n\lambda}\equiv T_x$, $U_{x+n\lambda}\equiv U_x$, mod q.

If $U_{\lambda'}$ be the first number of its series which is divisible by q, we shall have either $\lambda'=\lambda$, or $2\lambda'=\lambda$. In either case, the only numbers U which are divisible by q, are those whose indices are divisible by λ'; and the formula $\left[T_{m\lambda'}, \frac{U_{m\lambda'}}{q}\right]$ comprises all the solutions of the equation $T^2-Dq^2U^2=m^2$. Thus, in solving the equation $T^2-DU^2=m^2$, we can always substitute for D its quotient when divided by its greatest square divisor. (See Lagrange, Additions to Euler's Algebra, art. 78. Gauss, Disq. Arith. art. 201. Obs. 3 and 4.)

We may add, that if q be a prime (an uneven prime when $m=2$), and if q^{κ} and q^{μ} be the highest powers of q, dividing U_{λ} and n respectively, $q^{\kappa+\mu}$ will be the highest power of q dividing $U_{n\lambda}$. (Dirichlet, in Liouville's Journal, New Series, vol. i. p. 76.)

(vi.) The methods of Lagrange and Gauss are applicable to the equation $T^2-DU^2=4$, only when $D\equiv1$, mod 4; because they suppose the existence of an improperly primitive form of det. D. In all other cases the equation $T^2-DU^2=4$ may be divided by 4, and reduced to the form $T^2-DU^2=1$: viz. if $D\equiv0$, mod 4, T is even; and if $D\equiv2$, or $\equiv3$, mod 4, T and U are both even. A similar reduction takes place if $D\equiv1$, mod 8; the equation $T^2-DU^2=4$ admitting in that case only even solutions. But if $D\equiv5$, mod 8, $T^2-DU^2=4$ may or may not have uneven solutions; and no criterion is known for distinguishing *à priori* these two cases. If $T^2-DU^2=4$ admit of uneven solutions, its least solution $[T_1, U_1]$ will be uneven; its even solutions will be comprised in the formula $[T_{3n}, U_{3n}]$, and consequently $[\frac{1}{2}T_{3n}, \frac{1}{2}U_{3n}]$ will represent the solutions of $T^2-DU^2=1$.

(vii.) The equations $T^2-DU^2=-4$, $T^2-DU^2=-1$ are not resoluble for all values of D, but only for those values for which -1 is capable of representation by the principal form of det. D. Whenever the period of integral quotients in the development of $\sqrt{D}$ consists of an uneven number of terms, these equations will be resoluble, and conversely. This will always happen when D is a prime number of the form $4n+1$, and may happen in many other cases, but never can happen when D is divisible by any prime of the form $4n+3$. If $T^2-DU^2=-1$ be resoluble and $[T_1, U_1]$ be its least solution, the formula $[T_{2n+1}, U_{2n+1}]$ contains all its solutions, and $[T_{2n}, U_{2n}]$ all the solutions of $T^2-DU^2=1$. If, in addition to the supposition that $T^2-DU^2=-1$ is resoluble, we suppose that $T^2-DU^2=4$ admits of uneven solutions, $T^2-DU^2=-4$ will also admit of uneven solutions; and if $[T_1, U_1]$ be its least solution, $[T_{2n+1}, U_{2n+1}]$, $[T_{2n}, U_{2n}]$, $[\frac{1}{2}T_{6n+3}, \frac{1}{2}U_{6n+3}]$, $[\frac{1}{2}T_{6n}, \frac{1}{2}T_{6n}]$ will represent all the solutions of $T^2-DU^2=-4$, $=4$, $=-1$, and $=1$, respectively. It is evident that these considerations will frequently serve to abbreviate the process of finding the least solution of $T^2-DU^2=1$. (See a memoir of Euler's in the Comment. Arith. vol. ii. p. 35.)

(viii.) The "Canon Pellianus" of Degen (Havniæ 1817) contains a Table, giving for every not square value of D less than 1000, the least solution of the equation $T^2-DU^2=1$, together with the development of $\sqrt{D}$ in a continued fraction. Its arrangement will be seen in the following specimens:—

357	18, 1, 8, (2) 1, 33, 4, 17 180 3401
97	9, 1, 5, 1, 1, (1, 1) 1, 16, 3, 11, 8, (9, 9) 6377352, 62809633.

The numbers in the third and fourth rows are the least values of U and T in the equation $T^2-DU^2=1$. The first row of numbers is the period of integral quotients in the development of $\sqrt{D}$: it is continued only as far as the middle quotient, or the two middle quotients, after which the same quotients recur in an inverse order. Thus,

$$180=(1, 8, 2, 8, 1);$$
$$3401=(18, 1, 8, 2, 8, 1);$$
$$6377352=(1, 5, 1, 1, 1, 1, 1, 1, 5, 1, 18, 1, 5, 1, 1, 1, 1, 1, 1, 5, 1);$$
$$62809633=(9, 1, 5, 1, 1, 1, 1, 1, 1, 5, 1, 18, 1, 5, 1, 1, 1, 1, 1, 1, 5, 1).$$

The numbers in the second row are the denominators of the complete quotients; *i. e.* taken alternately positively and negatively, they are the extreme coefficients in the equations of the period. Thus the period of equations for $\sqrt{357}$ is [−33, −18, 1], [1, 18, −33], [−33, −15, 4], [4, 17, −17], [−17, −17, 4], [4, 15, −33]. The first half of the period of equations for $\sqrt{97}$ is [−16, −9, 1], [1, +9, −16], [−16, −7, 3], [3, 8, −11], [−11, −3, 8], [8, 5, −9], [−9, −4, 9], [9, +5, −8], [−8, −3, 11], [11, 8, −3], [−3, −7, 16], the second half being composed of the same equations in the same order but with their signs changed. The middle coefficients of the equations are not given in the Table; but if $[\alpha_\lambda, \beta_\lambda, \alpha_{\lambda+1}]$, $[\alpha_{\lambda+1}, \beta_{\lambda+1}, \alpha_{\lambda+2}]$ be two consecutive equations, of which the former determines the integral quotient μ_λ, they may be successively calculated by the formula $\beta_{\lambda+1}=\mu_\lambda\, \alpha_{\lambda+1}+\beta_\lambda$.

Lagrange has proved that if $x^2-Dy^2=H$, and H be $<\sqrt{D}$, $\frac{x}{y}$ is always a convergent to $\sqrt{D}$; so that a number less than $\sqrt{D}$ is or is not capable of representation by the principal form of det. D, according as it is or is not included among the numbers of the second row.

The second Table of the "Canon" contains the least solution of the equation $T^2-DU^2=-1$ for those values of D less than 1000 for which that equation is resoluble.

Mr. Cayley (Crelle, vol. liii. p. 369) has calculated the least solution of the equation $T^2-DU^2=4$, or $T^2-DU^2=-4$, for every number D of the form $8n+5$ less than 1000, for which those equations are resoluble in uneven numbers. This Table, as well as Degen's second Table, is implicitly contained in the first Table of the "Canon," as appears from the theorem of Lagrange just cited.

(ix.) The theory of the equations $T^2-DU^2=1$ and $=4$ is connected in a remarkable manner with that of the division of the circle*. Let $\lambda=2\mu+1$ represent an uneven number divisible by k unequal primes, but having no square divisor; let also the numbers less than λ and prime to it be represented by a or b, according as they satisfy the equation $\left(\frac{a}{\lambda}\right)=1$, or $\left(\frac{b}{\lambda}\right)=-1$; and let $X=0$ be the equation of the primitive λth roots of unity. The form of this equation (see art. 59) implies that $\Sigma\epsilon^{\frac{2ai\pi}{\lambda}}+\Sigma\epsilon^{\frac{2bi\pi}{\lambda}}=(-1)^k$; we have also the relation $\Sigma\epsilon^{\frac{2ai\pi}{\lambda}}-\Sigma\epsilon^{\frac{2bi\pi}{\lambda}}=i^{\mu^2}\sqrt{\lambda}$, which is easily deducible from the formulæ of

* See Dirichlet, "Sur la manière de résoudre l'équation $t^2-pu^2=1$ au moyen des fonctions circulaires," Crelle, vol. xvii. p. 286. Also Jacobi's note on the division of the circle, Crelle, vol. xxx. p. 173.

Gauss (see arts. 20 and 104 of this Report, or Dirichlet, Crelle, vol. xxi. pp. 141, 142). From these values of $\Sigma\epsilon^{\frac{2ai\pi}{\lambda}}$ and $\Sigma\epsilon^{\frac{2bi\pi}{\lambda}}$ we infer that $2\Pi\left(x-\epsilon^{\frac{2ai\pi}{\lambda}}\right)$ and $2\Pi\left(x-\epsilon^{\frac{2bi\pi}{\lambda}}\right)$ are two quantities of the form $Y+i^{\mu^2}Z\sqrt{\lambda}$, and $Y-i^{\mu^2}Z\sqrt{\lambda}$, Y and Z denoting integral functions of x with integral coefficients; *i. e.* that $4X=Y^2-(-1)^{\mu}\lambda Z^2$. From this equation, which is a generalization of that obtained by Gauss for the case when λ is a prime (Disq. Arith. art. 357), we can deduce a solution of the equation $T^2-\lambda Y^2=4$. In the formula $2\Pi\left(x-\epsilon^{\frac{2ai\pi}{\lambda}}\right)=Y+i^{\mu^2}Z\sqrt{\lambda}$, let us first write i for x, and then $-i$ for i, and let us denote by X_i, Y_i, Z_i, X_{-i}, Y_{-i}, Z_{-i} the values which X, Y, and Z acquire when i and $-i$ are written for x. We thus find, denoting the number of numbers less than λ and prime to it by λ',

$$4\Pi.\left(i-\epsilon^{\frac{2ai\pi}{\lambda}}\right)\left(-i-\epsilon^{-\frac{2ai\pi}{\lambda}}\right)=2^{\lambda'+2}\Pi\cos^2\left(\frac{\varpi}{4}+\frac{a\varpi}{\lambda}\right)$$
$$=[Y_iY_{-i}+\lambda Z_iZ_{-i}]+\sqrt{\lambda}[i^{\mu^2}Z_iY_{i-}+i^{-\mu^2}Z_{-i}Y_i];$$

or, writing

$$T \text{ for } \tfrac{1}{2}[Y_iY_{-i}+\lambda Z_iZ_{-i}],\ U \text{ for } \tfrac{1}{2}[i^{\mu^2}Z_iY_{-i}+i^{-\mu^2}Z_{-i}Y_i],$$

and observing that $X_iX_{-i}=1$,

$$\tfrac{1}{2}(T+U\sqrt{\lambda})=2^{\lambda'}\Pi\cos^2\left(\frac{\varpi}{4}+\frac{a\varpi}{\lambda}\right),\ T^2-\lambda U^2=4,$$

where it is easily seen that T and U are integral numbers. When μ is even, we may obtain a solution of the equation more simply by writing $+1$ or -1 for x. (See the notes of Jacobi and Dirichlet already referred to.)

It is to be observed, however, that the solution obtained by these methods is not in general the least solution. Its ordinal place in the series of solutions depends (as we shall hereafter see) on the number of classes of forms of det. D.

97. *Solution of the General Indeterminate Equation of the second degree.*—The solution of the indeterminate equation $ax^2+2bxy+cy^2+2dx+2ey+f=0$ depends on the problem of the representation of a given number by a quadratic form. We confine ourselves to the case which presents the greatest complexity, that in which $b^2-ac=D$ is a positive and not square number. The methods of solution contained in Euler's Memoirs relating to it (see Comment. Arith. vol. i. pp. 4, 297, 549, 570, vol. ii. p. 263; and the Algebra, vol. ii. cap. vi.) are incomplete in several respects: first, because Euler always assumes that a single solution is known, and only proposes to deduce all the solutions from it; secondly, because it is not possible, from a given solution, to deduce any other solutions than those which belong to the same set with the given solution, whereas the equation may admit of solutions belonging to different sets; and lastly, because he gives no method for distinguishing between the integral and fractional values contained in the formulæ by which x and y are expressed. The first complete solution of the problem was given by Lagrange in his Memoir "Sur la solution des Problèmes Indéterminés du second degré" (Hist. de l'Académie de Berlin for 1767, vol. xxiii. p. 165–311). But the following method of solution, which is different in some respects and much simpler, will be found in a subsequent memoir, "Nouvelle méthode pour résoudre les problèmes indéterminés en nombres entiers" (Hist. de l'Académie de Berlin for 1767, vol. xxiv. p. 181); and in the Additions to Euler's Algebra (paragraph 7). If we multiply by aD and write p for $ax+by+d$, q for $(b^2-ac)y+(bd-ae)$, M for $(bd-ae)^2-(b^2-ac)(d^2-af)$, the given equation becomes $q^2-Dp^2=M$. Confining ourselves

to the primitive representations of M by q^2-Dp^2 (the derived representations, corresponding to the different square divisors of M, are to be treated separately by the same method), we see that, since p and M are prime, q is of the form $Mr+\Omega p$, where r and Ω are two new indeterminates of which the latter may be supposed $< [\frac{1}{2} M]$. On substituting this value for q, it will appear that $N=\frac{\Omega^2-D}{M}$ is necessarily integral, *i. e.* that Ω is one of the roots of the congruence $\Omega^2-D\equiv 0$, mod M; and the equation will assume the form $Np^2+2\Omega pr+Mr^2=1$, in which every admissible value of Ω is to be employed in succession. The development of either root of the equation $N+2\Omega\theta+M\theta^2=0$ will give all the values of p and r which satisfy the equation $Np^2+2\Omega pr+Mr^2=1$, because 1 is the *minimum* value which the form (N, Ω, M) can assume. (See the Additions, paragraph 2, and especially arts. 33–35.) Or again, if we apply the transformation of art. 92 to the form (N, Ω, M), we obtain an equation of the type $Px'^2+2Qx'y'+Ry'^2=1$, in which $Q^2-PR=D$, and $P<\sqrt{D}$; whence, if $x''=Px'+Qy'$, we finally deduce $x''^2-Dy'^2=P$, all the solutions of which (see art. 96, viii.) are necessarily given by the development of $\sqrt{D}$ in a continued fraction. Applying either of these methods (the latter is not given in the Memoir, but only in the Additions to Euler's Algebra) to every equation of the form $Np^2+2\Omega p^2+Mr^2=1$ which can be deduced from the equation $q^2-Dp^2=M$, or from the equations of similar form obtained by replacing M by the quotient which it leaves when divided by any one of its square divisors, we obtain a finite number of formulæ of the type

$$x=\frac{\alpha T+\beta U+\gamma}{\delta},\ y=\frac{\alpha' T+\beta' U+\gamma'}{\delta'},$$

[T, U] denoting any solution of the equation $T^2-DU^2=1$. These formulæ are fractional; but by attending to the principle of art. 96, v., we can ascertain for each pair of formulæ whether they contain any integral values or not, and if they do contain any, we can substitute for the single pair of fractional formulæ a finite number of pairs not containing any fraction.

The form in which the solution of this problem has been exhibited by Gauss is remarkable for its elegance. Let $\begin{vmatrix} a, b, d \\ b, c, e \\ d, e, f \end{vmatrix}=\Delta$, and δ representing the greatest common divisor of b^2-ac, $cd-be$, $ae-bd$, let $\frac{D}{\delta}=D'$, $\frac{\Delta}{\delta}=\Delta'$, $\frac{cd-be}{\delta}=p$, $\frac{ae-bd}{\delta}=q$, then putting $D'x=X+p$, $D'y=Y+q$, we find $aX^2+2bXY+cY^2=D'\Delta'$. If $[X_n, Y_n]$ denote indefinitely any representation of $D'\Delta'$ by (a, b, c), we have only to separate (by Lagrange's method) those values of X_n, Y_n which satisfy the congruences $X_n+p\equiv 0, Y^n+q\equiv 0$, mod D', from those which do not, and we shall obtain a finite number of formulæ, exhibiting the complete solution required.

98. *Distribution of Classes into Orders and Genera.*—The classes of forms of any given positive or negative determinant D, are divided by Gauss into Orders, and the classes belonging to each order into Genera. Two classes, represented by the forms (a, b, c), (a', b', c'), belong to the same order, when the greatest common divisors of a, b, c and $a, 2b, c$ are respectively equal to those of a', b', c', and of $a', 2b', c'$. Thus the properly primitive classes form an order by themselves; and the improperly primitive classes form another order. To obtain the subdivision of orders into genera, it is only necessary to consider the primitive classes; because we can deduce the subdivision of a derived order of classes from the subdivision of the

primitive order from which it is derived. The subdivision into genera of the order of properly primitive classes depends on the principles contained in the following equations, in which q is an uneven prime dividing D, m and m' uneven numbers prime to q, and capable of representation by the same properly primitive form of determinant D.

(i.) $\left(\frac{m}{q}\right)=\left(\frac{m'}{q}\right)$

(ii.) If $D\equiv 3$, mod 4, $(-1)^{\frac{m-1}{2}}=(-1)^{\frac{m'-1}{2}}$.

(iii.) If $D\equiv 2$, mod 8, $(-1)^{\frac{m^2-1}{8}}=(-1)^{\frac{m'^2-1}{8}}$.

(iv.) If $D\equiv 6$, mod 8, $(-1)^{\frac{m-1}{2}+\frac{m^2-1}{8}}=(-1)^{\frac{m'-1}{2}+\frac{m'^2-1}{8}}$.

(v.) If $D\equiv 4$, mod 8, $(-1)^{\frac{m-1}{2}}=(-1)^{\frac{m-1}{2}}$.

(vi.) If $D\equiv 0$, mod 8, $(-1)^{\frac{m-1}{2}}=(-1)^{\frac{m'-1}{2}}$; and

$$(-1)^{\frac{m^2-1}{8}}=(-1)^{\frac{m'^2-1}{8}}.$$

The interpretation of these symbolic formulæ is very simple. Thus, the formula (i.) expresses that—

"The numbers prime to any prime divisor q of D which can be represented by f the same properly primitive form of det. D are either all quadratic residues of q, or else all quadratic non-residues."

Again, the formula (iv.) expresses that "if D be of the form $8n+6$, the uneven numbers that can be represented by f are either all included in one of the two forms $8n+1$, $8n+3$, or else in one of the two $8n-1$, $8n-3$."

All the formulæ are deducible by the most elementary considerations from the three equations

$$m=ax^2+2bxy+cy^2,\quad m'=ax'^2+2bx'y'+cy'^2,$$
$$(ax^2+2bxy+cy^2)(ax'^2+2bx'y'+cy'^2)=(axx'+b[xy'+x'y]+cyy')^2$$
$$-D(xy'-x'y)^2.$$

Thus we find immediately $\left(\frac{mm'}{q}\right)=1$, or $\left(\frac{m}{q}\right)=\left(\frac{m'}{q}\right)$. And again, if $D\equiv 6$, mod 8, the last equation shows us that $axx'+b[xy'+x'y]+cyy'$ is uneven; and consequently $mm'\equiv 1-6(xy'-x'y)^2$, mod 8, i. e. $mm'\equiv +3$, or $\equiv +1$, mod 8, according as $xy'-x'y$ is uneven or even; whence m and m' are either both of the forms $8n+1$, $8n+3$, or else both of the forms $8n-1$, $8n-3$.

The form f is said to have the *particular character* $\left(\frac{f}{q}\right)=+1$, or $\left(\frac{f}{q}\right)=-1$, according as the numbers (prime to q) which are represented by it satisfy the equation $\left(\frac{m}{q}\right)=1$, or $\left(\frac{m}{q}\right)=-1$; and we are to understand in the same way the expressions that f has the particular character $(-1)^{\frac{f^2-1}{8}}=+1$, or $=-1$, &c. Every particular character of a form belongs equally to all forms of the same class, and is therefore termed a particular character of the class. The complex of the particular characters of a form or class constitutes its *complete* or *generic character*; and those classes which have the same complete character are considered to belong to the same genus: so that the complete character of a form is possessed not only by every form of the same class, but by every form of any class belonging to the same genus.

To enable the reader to form with facility the complete character of any given properly primitive class, we add the following Table, taken from Dirichlet (Crelle, vol. xix. p. 338), in which S^2 denotes the greatest square dividing D; P or 2P is the quotient $\frac{D}{S^2}$, according as that quotient is uneven or even; $p, p' \ldots$ are the prime divisors of P; and r, r' the uneven primes dividing S, but not P.

I. $D=PS^2$, $P\equiv 1$, mod 4.

(α) $S\equiv 1$, mod 2.

$$\left(\frac{f}{p}\right), \left(\frac{f}{p'}\right), \ldots \Big| \left(\frac{f}{r}\right), \left(\frac{f}{r'}\right), \ldots$$

(β) $S\equiv 2$, mod 4.

$$\left(\frac{f}{p}\right), \left(\frac{f}{p'}\right), \ldots \Big| (-1)^{\frac{f-1}{2}}, \left(\frac{f}{r}\right), \left(\frac{f}{r'}\right), \ldots$$

(γ) $S\equiv 0$, mod 4.

$$\left(\frac{f}{p}\right), \left(\frac{f}{p'}\right), \ldots \Big| (-1)^{\frac{f-1}{2}}, (-1)^{\frac{f^2-1}{8}}, \left(\frac{f}{r}\right), \left(\frac{f}{r'}\right), \ldots$$

II. $D=PS^2$, $P\equiv 3$, mod 4.

(α) $S\equiv 1$, mod 2.

$$(-1)^{\frac{f-1}{2}}, \left(\frac{f}{p}\right), \left(\frac{f}{p'}\right), \ldots \Big| \left(\frac{f}{r}\right), \left(\frac{f}{r'}\right), \ldots$$

(β) $S\equiv 2$, mod 4.

$$(-1)^{\frac{f-1}{2}}, \left(\frac{f}{p}\right), \left(\frac{f}{p'}\right), \ldots \Big| \left(\frac{f}{r}\right), \left(\frac{f}{r'}\right), \ldots$$

(γ) $S\equiv 0$, mod 4.

$$(-1)^{\frac{f-1}{2}}, \left(\frac{f}{p}\right), \left(\frac{f}{p'}\right), \ldots \Big| (-1)^{\frac{f^2-1}{8}}, \left(\frac{f}{r}\right), \left(\frac{f}{r'}\right), \ldots$$

III. $D=2PS^2$, $P\equiv 1$, mod 4.

(α) $S\equiv 1$, mod 2.

$$(-1)^{\frac{f^2-1}{8}}, \left(\frac{f}{p}\right), \left(\frac{f}{p'}\right), \ldots \Big| \left(\frac{f}{r}\right), \left(\frac{f}{r'}\right), \ldots$$

(β) $S\equiv 0$, mod 2.

$$(-1)^{\frac{f^2-1}{8}}, \left(\frac{f}{p}\right), \left(\frac{f}{p'}\right), \ldots \Big| (-1)^{\frac{f-1}{2}}, \left(\frac{f}{r}\right), \left(\frac{f}{r'}\right), \ldots$$

IV. $D=2PS^2$, $P\equiv 3$, mod 4.

(α) $S\equiv 1$, mod 2.

$$(-1)^{\frac{f-1}{2}+\frac{f^2-1}{8}}, \left(\frac{f}{p}\right), \left(\frac{f}{p'}\right), \ldots \Big| \left(\frac{f}{r}\right), \left(\frac{f}{r'}\right), \ldots$$

(β) $S\equiv 0$, mod 2.

$$(-1)^{\frac{f-1}{2}}, (-1)^{\frac{f^2-1}{8}}, \left(\frac{f}{p}\right), \left(\frac{f}{p'}\right), \ldots \Big| \left(\frac{f}{r}\right), \left(\frac{f}{r}\right), \ldots$$

It appears from this Table, that if μ be the number of uneven primes which divide D, the total number of generic characters that can be formed by combining the particular characters in every possible way is 2^{μ} when $D\equiv 1$ or 5, mod 8; $2^{\mu+2}$ when $D\equiv 0$, mod 8; and $2^{\mu+1}$ in every other case. But it follows from the law of quadratic reciprocity, that one-half of these complete characters are impossible; *i. e.* that no quadratic form characterized by them can exist. To see this, we observe that if m be a positive and uneven number prime to D, and capable of primitive representation by f, the congruence $\Omega^2-D\equiv 0$, mod m, is resoluble; and consequently $\left(\frac{D}{m}\right)=+1$. Therefore also $\left(\frac{P}{m}\right)=1$, or $\left(\frac{2P}{m}\right)=1$, according as D is of the form PS^2 or $2PS^2$. In the first case we have $\left(\frac{m}{P}\right)=(-1)^{\frac{1}{4}(m-1)(P-1)}$, or

$$\left(\frac{m}{p}\right)\left(\frac{m}{p'}\right)\ldots=(-1)^{\frac{1}{4}(m-1)(P-1)};$$

in the other case $\left(\frac{2}{m}\right)\left(\frac{P}{m}\right)=1$; *i. e.* $\left(\frac{m}{P}\right)=(-1)^{\frac{1}{4}(m-1)(P-1)+\frac{m^2-1}{8}}$, or

$$\left(\frac{m}{p}\right)\left(\frac{m}{p'}\right)\ldots=(-1)^{\frac{1}{4}(m-1)(P-1)+\frac{m^2-1}{8}}.$$

A comparison of these equations with the preceding Table will show that the product of the particular characters which stand before the line of division in the Table is equal to +1 in the case of any really existing genus; *i. e.* that precisely one-half of the whole number of complete generic characters are impossible. We shall hereafter see that the remaining half of the generic characters correspond to actually existing genera, and that each genus contains an equal number of classes. That genus, every particular character of which is a positive unit, is called the *principal* genus; it evidently contains the principal class, and is therefore, in every case, an actually existing genus.

Since the extreme coefficients of a form are numbers represented by it, and since, further, if the form be properly primitive, one or other of them is prime to 2 and to any prime divisor of the determinant, we see that the generic character of a form can always be ascertained by considering the values of its first and last coefficients. Thus the complete character of the form (11, 2, 15), of which the det. is $-161=-7\times 23$ (case II. (α) in the Table), is $\left(\frac{f}{7}\right)=1$, $\left(\frac{f}{23}\right)=-1$, $(-1)^{\frac{f-1}{2}}=-1$; that of (5, 2, 33) is $\left(\frac{f}{7}\right)=-1$, $\left(\frac{f}{23}\right)=-1$, $(-1)^{\frac{f-1}{2}}=+1$.

Two forms, which have different generic characters, cannot be equivalent; nor can a number be represented by a form if its character is incompatible with the generic character of the form. It is therefore convenient, in any problem of equivalence or representation, to begin by comparing the generic characters of the given forms with one another, or with the characters of the given numbers.

The uneven numbers prime to the determinant, which are represented by forms of the same genus, are contained in one or other of a certain number of linear forms. If R denote the product of the primes $r, r', \ldots$ already defined, and if θ be any term of a system of residues prime to $2^k PR$, where k is 1, when $D\equiv 1$ or 5, mod 8, 3 when $D\equiv 2$, 6, or 0, and 2 in every other case, the numbers contained in the formula $2^k PR+\theta$ can be represented only by forms belonging to that genus the character of which coincides with the character of the number θ. It is clear that one half of the linear forms, included in the formula $2^k\mathrm{PR}+\theta$, do not satisfy the condition of possibility indicated in the Table, and are therefore incompatible with any quadratic form of determinant D; while the remaining half of those linear forms will be equally distributed among the actually existing genera; so that there will be either $\Pi\frac{1}{2}(p-1)\frac{1}{2}(r-1)$ or $2\Pi\frac{1}{2}(p-1)\frac{1}{2}(r-1)$ linear forms proper to each genus. But although no number contained in any one of the first-named linear forms can be represented by a form of determinant D, yet it is not to be inferred that every number m contained in the other half of the linear forms is capable of such representation; for from the linear form of m, we can indeed infer the equation $\left(\frac{\mathrm{D}}{m}\right)=1$; but, if m be not a prime, or at least the product of a prime by a square, we cannot from this equation infer the resolubility of the congruence $\Omega^2\equiv\mathrm{D}$, mod m, or of any congruence of the form $\Omega^2\equiv\mathrm{D}$, mod $\frac{m}{d^2}$. We may add that if we assume the theorem that every arithmetic progression, the terms of which are prime to their common difference, contains prime numbers, the consideration of the case in which m is a prime establishes the actual existence of every genus the character of which satisfies the condition of possibility. (Crelle, vol. xviii. p. 269.)

If m be an uneven number not divisible by q, a prime divisor of D, and if the double of m can be represented by an improperly primitive form f of det. D, we attribute to f the particular character $\left(\frac{f}{q}\right)=+1$, or $=-1$, according as $\left(\frac{m}{q}\right)=+1$, or $=-1$; and to form the complete character of f, we may use the Table

$$\mathrm{D}=\mathrm{PS}^2,\quad \mathrm{P}\equiv 1, \text{ mod } 4,\quad \mathrm{S}\equiv 1, \text{ mod } 2.$$

$$\left(\frac{f}{p}\right),\ \left(\frac{f}{p'}\right),\ldots\ \Big|\ \left(\frac{f}{r}\right),\ \left(\frac{f}{r'}\right),\ldots\ ^*$$

99. In the preceding articles we have briefly recapitulated the definitions and principles which constitute the elements of the theory of quadratic forms. We have hitherto followed closely the 5th section of the Disq. Arith. (arts. 153–222 and 223–233); but before we proceed to an examination of the remainder of that section, it will be convenient to place before the reader an account of the method employed by Lejeune Dirichlet in his great memoir, "Recherches sur diverses applications de l'analyse infinitésimale à la théorie des nombres," for the determination of the number of quadratic forms of a given positive or negative determinant.

* All the results of this article are given in the Disq. Arith. arts. 223–232; but as Gauss does not employ the symbol of reciprocity, we have preferred to follow the notation of Dirichlet. It is also to be noticed that Gauss does not use the law of quadratic reciprocity to demonstrate the impossibility of one-half of the generic characters; for, as we shall hereafter see, this impossibility is proved in the Disq. Arith. (art. 261) independently of the law of reciprocity, and is then employed to establish that law. (Gauss's second demonstration, see Disq. Arith. art. 262.) There is also an unimportant difference between Dirichlet and Gauss with respect to the definition of the generic character of an improperly primitive form; for Gauss obtains the generic character (see art. 232) by considering the numbers represented by the form, and not the halves of those numbers. But he also observes (art. 227, and 256, VI.) that each improperly primitive class is connected in a particular manner (to which we shall again refer) with one or with three properly primitive classes; and that this consideration may be employed to divide the improperly primitive classes into genera. And it will be found that the complete character which Dirichlet's definition attributes to an improperly primitive form is, in fact, the complete character of the properly primitive class or classes with which it is connected.

It appears from the Additamenta to art. 306, X. of the Disq. Arith., that Gauss, at the time of the publication of that work, had already succeeded in effecting this determination; and the method by which he effected it will at length appear in the second volume of the complete edition of his works, the publication of which is now promised by the Society of Göttingen. Nevertheless the originality of Dirichlet in this celebrated investigation is unquestionable, as there is nothing whatever in the Disq. Arith. to suggest either the form of the result, or the method by which it is obtained*.

We propose, in what follows, to give as full an analysis as our limits will permit of the contents of the memoir. Its first section contains certain principles relative to the theory of series.

(i.) "If $k_1 \leqq k_2 \leqq k_3 \leqq k_4 \ldots$ be a series of continually increasing positive quantities; and if the ratio $\frac{n}{k_n}$ continually tend to a finite limit α (that is to say, if, δ denoting a given positive quantity, however small, we can always assign a finite value of $n=\mathrm{N}$, such that for all values of n surpassing N, the inequalities

$$\alpha-\delta<\frac{n}{k_n}<\alpha+\delta$$

are satisfied), the limit of the expression $\rho \sum_{n=1}^{n=\infty} \frac{1}{k_n^{1+\rho}}$, when the positive quantity ρ is diminished without limit, is α."†

For $\rho \sum_{n=1}^{n=\infty} \frac{1}{k_n^{1+\rho}}=\rho \sum_{n=1}^{n=\mathrm{N}} \frac{1}{k_n^{1+\rho}}+\rho \sum_{n=\mathrm{N}+1}^{n=\infty} \frac{1}{k_n^{1+\rho}}$, N denoting a finite number; and by virtue of the inequalities written above

$$\sum_{n=\mathrm{N}+1}^{n=\infty} \frac{(\alpha-\delta)^{1+\rho}}{n^{1+\rho}}<\sum_{n=\mathrm{N}+1}^{n=\infty} \frac{1}{k_n^{1+\rho}}<\sum_{n=\mathrm{N}+1}^{n=\infty} \frac{(\alpha+\delta)^{1+\rho}}{n^{1+\rho}}.$$

* The following is a list of the papers of Lejeune Dirichlet which relate to the theory of quadratic forms :—

1. Sur l'usage des séries infinies dans la théorie des nombres.—Crelle, vol. xviii. p. 259.
2. Recherches sur diverses applications de l'analyse infinitésimale à la théorie des nombres.—Crelle, vol. xix. p. 324, and xxi. pp. 1, 134.
3. Auszug aus einer der Akademie der Wissenschaften zu Berlin am 5 März 1840 vorgelesenen Abhandlung. (Crelle, vol. xxi. p. 98, or the Monatsberichte for 1840, p. 49.)
This paper is an abstract of an unpublished memoir containing the demonstration of the theorem that every properly primitive form represents an infinite number of primes.
4. Untersuchungen über die Theorie der complexen Zahlen. (Crelle, vol. xxii. p. 375, or in the Monatsberichte for 1841, p. 190.) An abstract of the following memoir.
5. Recherches sur les formes quadratiques à coëfficients et à indéterminés complexes.—Crelle, vol. xxiv. p. 291.
6. Sur un théorème relatif aux séries. (Liouville, New Series, vol. i. p. 80, or Crelle, vol. liii. p. 130.)
7. Sur une propriété des formes quadratiques à déterminant positif. (Monatsberichte for July 16, 1855, or Liouville, New Series, vol. i. p. 76, or Crelle, vol. liii. p. 127.)
8. Vereinfachung der Theorie der binären quadratischen Formen von positiver Determinante. (Memoirs of the Berlin Academy for 1854, p. 99, or, with additions by the author, in Liouville, New Series, vol. ii. p. 353.)
9. Démonstration nouvelle d'une proposition relative à la théorie des formes quadratiques.—Liouville, New Series, vol. ii. p. 273.
10. De formarum binarium secundi gradus compositione.—Crelle, vol. xlvii. p. 155.

The three last papers contain important simplifications of theories which appear in a very complicated form in the Disq. Arith. To two of them we have already referred (arts. 93, 94).

† This theorem is a generalization of that in the memoir (Crelle, vol. xix. p. 326). It is given by Dirichlet in No. 6 of the preceding list.

Observing that $\lim \rho \sum_{n=N+1}^{n=\infty} \frac{1}{n^{1+\rho}}$ is intermediate between

$$\lim \rho \int_{N+1}^{\infty} \frac{dx}{x^{1+\rho}} \text{ and } \lim \rho \int_{N}^{\infty} \frac{dx}{x^{1+\rho}},$$

and is consequently unity, we infer from the last inequalities that

$$\lim \rho \sum_{n=N+1}^{n=\infty} \frac{1}{k_n^{1+\rho}},$$

and therefore also

$$\lim \rho \sum_{n=1}^{n=\infty} \frac{1}{k_n^{1+\rho}},$$

which is identical with it, because

$$\lim \rho \sum_{n=1}^{n=N} \frac{1}{n^{1+\rho}}=0$$

differs from α by a quantity comminuent with δ; *i. e.* $\lim \rho \sum_{n=1}^{n=\infty} \frac{1}{k_n^{1+\rho}}=\alpha$, since by hypothesis δ is a quantity as small as we please.

(ii.) A convergent infinite series may be convergent in two very different ways. It may be convergent, and always have the same sum irrespective of the arrangement of its terms; or it may be convergent for certain arrangements of its terms, giving the same or different sums for these different arrangements, and divergent for other arrangements. We suppose, however, that we consider only such different arrangements of the terms of a series as are compatible with the condition that any term which occupies a *finitesimal* place in any one arrangement should occupy a *finitesimal* place in every other arrangement*. Thus the series

$$\frac{1}{1^{1+\rho}}+\frac{1}{2^{1+\rho}}+\frac{1}{3^{1+\rho}}+\dots, \rho>0,$$

is convergent, and has the same sum in whatever order we sum its terms; but of the two series

$$1-\frac{1}{2^{\frac{1}{2}}}+\frac{1}{3^{\frac{1}{2}}}-\frac{1}{4^{\frac{1}{2}}}+\frac{1}{5^{\frac{1}{2}}}-\frac{1}{6^{\frac{1}{2}}}+\dots$$

$$1+\frac{1}{3^{\frac{1}{2}}}-\frac{1}{2^{\frac{1}{2}}}+\frac{1}{5^{\frac{1}{2}}}+\frac{1}{7^{\frac{1}{2}}}-\frac{1}{4^{\frac{1}{2}}}+\dots$$

* This condition is necessary, because without it the sum of no series whatever would be independent of the arrangement of its terms, if by the sum of a series we understand the limit to which we approximate by the continual addition of its terms in the order in which they are given. For example, the series cited in the text,

$$\frac{1}{1^{1+\rho}}+\frac{1}{2^{1+\rho}}+\frac{1}{3^{1+\rho}}+\dots, \rho>0,$$

is convergent, and its sum is irrespective of the arrangement of its terms, provided that arrangement satisfy the condition enunciated in the text. But if we were to arrange the terms of the series in an order regulated (say) by the number of primes dividing their denominators, the limit to which we should continually approach by adding together the terms taken in their new order, would be $\Sigma \frac{1}{p^{1+\rho}}$, in which p denotes any prime, and not $\Sigma \frac{1}{n^{1+\rho}}$, in which n denotes any integer.

only the first is convergent; while the two series

$$1-\frac{1}{2}+\frac{1}{3}-\frac{1}{4}+\frac{1}{5}-\frac{1}{6}+\dots$$

$$1+\frac{1}{3}-\frac{1}{2}+\frac{1}{5}+\frac{1}{7}-\frac{1}{6}+\dots$$

are both convergent, but have two very different sums*.

These observations will show the importance of the following prpoosition†. "If c_n be a periodic function of n, satisfying the equations

$$c_{n+k}=c_n,$$
$$c_1+c_2+c_3+\dots+c_k=0,$$

the series $\sum_{n=1}^{n=\infty}\frac{c_n}{n^s}$ in which the terms are taken in their natural order, is convergent for all values of s superior to zero, and its sum is a continuous function of s."

For if we add together the k consecutive terms

$$\frac{c_1}{(km+1)^s}+\frac{c_2}{(km+2)^s}+\dots+\frac{c_k}{(km+k)^s},$$

we obtain a fraction of which the denominator is of the order ks in respect of m, while the numerator is only of the order $(k-1)s-1$, because the coefficient of $m^{(k-1)s}$ is zero. We may therefore replace the given series by a series of the form $\sum_{m=1}^{m=\infty}\frac{1}{\phi(m)}$, in which $\phi(m)$ is a function of the order $1+s$ in respect of m. This series is always convergent for positive values of s; its convergence is irrespective of the arrangement of its terms, and its sum is a continuous function of s, because $\phi(m)$ is a continuous function of s. The given series is therefore also convergent, and its sum is a continuous function of s.

100. The second section of the memoir refers to the symbols of reciprocity of Jacobi and Legendre (arts. 15, 16, and 17 of this Report).

The third and fourth sections contain the principal theorems relating to the generic characters of quadratic forms, and to the representation of numbers. There is only one of these theorems to which we need direct our attention here, as the others have already come before us in the preceding articles.

Let (a, b, c) be a primitive form of the positive determinant D; $(a, b, c)(x_0, y_0)^2=M$ a positive number represented by (a, b, c); m the greatest common divisor of $a, 2b, c$; [T, U] the least positive solution of $T^2-DU^2=m^2$; so that if $x_n=\frac{1}{m}[T_n x_0-U_n(bx_0+cy_0)]$, $y_n=\frac{1}{m}[T_n y_0+U_n(a x_0+b y_0)]$, the two formulæ $[x_n, y_n]$ and $[-x_n, -y_n]$ will together express every representation of M, which belongs to the same set as $[x_0, y_0]$. Similarly, let $[x'_n, y'_n]$, $[-x'_n, -y'_n]$ denote a complete set of representations of the positive number M′ by (a, b, c).

If we trace the hyperbola represented by the equation $ax^2+2bxy+cy^2=1$ referred to rectangular axes, the diameters included in the formula $y=\frac{y_k}{x_k}x$, in which k is to receive all values from $-\infty$ to $+\infty$, will form a pencil of

* These illustrations are taken from the Memoir on the Arithmetical Progression in the Berlin Memoirs for 1837, pp. 48 and 49.

† The demonstration in the text is a little simpler than that given by Dirichlet, who uses the function Γ to express the sum of the series.

lines, which all meet the curve, and which, commencing with the asymptote $y=-\frac{a}{\sqrt{D}+b}x$, continually recede from it, and approximate to the asymptote $y=\frac{a}{\sqrt{D}-b}x$. The sectorial area contained between any two consecutive lines of this pencil and either branch of the hyperbola is constant and equal to $\frac{1}{2}\cdot\frac{1}{\sqrt{D}}\log\frac{(T+U\sqrt{D})}{m}$; as may be ascertained by employing polar coordinates. Since the same observations apply to the pencil $y=\frac{y'_n}{x'_n}x$, we infer that the lines of these two pencils lie alternately, unless the two pencils coincide. Let us now suppose that in the form (a, b, c), a is positive and c negative; so that the axis of x does, and the axis of y does not cut the curve. On this supposition the values of $\frac{y_n}{x_n}$ and of $\frac{y'_n}{x'_n}$ continually increase from $-\frac{a}{\sqrt{D}+b}$ to $\frac{a}{\sqrt{D}-b}$ as n increases from $-\infty$ to $+\infty$. The alternate position of the lines of the two pencils gives, in this case, the theorem,—

"The inequalities

$$\frac{y'_k}{x'_k}<\frac{y_n}{x_n}\leqq\frac{y'_{k+1}}{x'_{k+1}},$$

in which k represents any given number, are satisfied for one value of n, and one only." If, taking a for M′ and [1, 0] for $[x'_0, y'_0]$, we put $k=0$, we obtain the conclusion,—

"Each set of representations of the positive number M by the form (a, b, c), in which a is positive and c negative, contains one and only one representation which satisfies the inequalities

$$x_n>0,\ y_n>0,\ y_n\leqq\frac{aU}{T-bU}x_n."$$

It is in this form that the theorem appears in Dirichlet's memoir. We may add that any values of x and y which satisfy these inequalities will give a positive value to (a, b, c); for such a pair of values will correspond to a point situated in the internal angle between the asymptotes of the hyperbola.

The fifth section contains the demonstration of the theorem, that if Δ denote the absolute value of D, and $\psi(2\Delta)$ be the number of numbers less than 2Δ and prime to it, a properly primitive form of determinant D will acquire a value prime to 2D, if its indeterminates x and y satisfy any one of a certain set of $2\Delta\psi(2\Delta)$ congruential conditions included among the $4\Delta^2$ conditions represented by the formulæ

$$x=\alpha, \bmod 2\Delta;\quad y=\beta, \bmod 2\Delta,$$

in which both α and β represent any term of a complete system of residues, mod 2Δ; but will acquire a value not prime to 2D, if x and y satisfy any of the other congruential conditions.

If the form be improperly primitive, the number of congruential conditions that will render its value unevenly even and prime to Δ will be $\Delta\psi(\Delta)$, or $3\Delta\psi(\Delta)$, according as $D\equiv 1$, or $\equiv 5$, mod 8.

These theorems are easily demonstrated by considering separately the prime divisors of Δ. For example, if the form (a, b, c) be improperly primitive, and p be a prime divisor of D, since either a or c is prime to p, let a be prime to p; then $(ax+by)^2-Dy^2$ will be prime to p, when $ax+by$ is so; *i. e.* it will be prime to p, for $p(p-1)$ combinations of the residues (mod p) of x and y; or, if p^n be the highest power of p dividing D, for $p^{2n-1}(p-1)$ combinations of the residues of x and y, mod p^n. Again, the 4 combinations of residues for the modulus 2 will give $\frac{1}{2}(a,b,c)$ the values 0, $\frac{1}{2}a_2$, $\frac{1}{2}c_2$, $\frac{1}{2}a+b+\frac{1}{2}c$, of which it is easily seen that one or three will be uneven, according as $ac\equiv 0$, or 4, mod 8; *i. e.* according as $D\equiv 1$, or 5, mod 8. The combination of these results will give Dirichlet's theorem.

101. *Series expressing the number of Primitive Classes.*—The sixth section of the memoir contains the demonstration of the formulæ which express in the form of an infinite series the number of classes of properly and improperly primitive quadratic forms of a given determinant. We shall abbreviate the demonstration of these formulæ by using the theorem of art. 87.

Let h be the number of properly primitive classes of determinant D; we shall first suppose D to be negative, and $=-\Delta$; let also (a_1,b_1,c_1), (a_2,b_2,c_2), ... (a_h,b_h,c_h) be a system of forms representing the properly primitive classes of that determinant; and let us consider the sum

$$S=\Sigma_1\frac{1}{(a_1x^2+2b_1xy+c_1y^2)^s}+\Sigma_2\frac{1}{(a_2x^2+2b_2xy+c_2y^2)^s}+\dots$$
$$+\Sigma_h\frac{1}{a_hx^2+2b_hxy+c_hy^2)^s},$$

the sign of summation Σ_k extending to all values of x and y from $-\infty$ to $+\infty$, which give the form (a_k,b_k,c_k), a value prime to Δ. By the theorem of art. 87, any uneven number n prime to Δ is capable of $2\Sigma\left(\frac{D}{d}\right)$ representations by the properly primitive forms of determinant D (for there are $\Sigma\left(\frac{D}{d}\right)$ sets of representations, and each set contains two*). We have therefore the equation

$$S=2\Sigma\left[\Sigma\left(\frac{D}{d}\right)\frac{1}{n^s}\right] \quad \dots\dots\dots\dots \quad (a)$$

(the inner sign of summation referring to every divisor d of n; and the outer sign extending to every positive value of n prime to 2Δ). If we write n for d, and nn' for n, so that n and n' each represent any positive number prime to 2Δ, this equation assumes the simpler form

$$S=2\Sigma\left(\frac{D}{n}\right)\frac{1}{(nn')^s}, \quad \dots\dots\dots\dots \quad (b)$$

the sign Σ indicating two independent summations with respect to n and n'; or, if we perform the two summations separately, and omit the accent,

$$S=2\Sigma\frac{1}{n^s}\Sigma\left(\frac{D}{n}\right)\frac{1}{n^s}. \quad \dots\dots\dots\dots \quad (c)$$

To deduce an expression for h from this equation, we write $1+\rho$ for s, and multiplying each side by ρ, we suppose ρ to be positive and to diminish without limit. In order to find the limit of ρS on this supposition, we consider separately the partial sums, such as $\rho\Sigma\frac{1}{(ax^2+2bxy+cy^2)^{1+\rho}}$, of which it is composed.

* If $\Delta=1$, each set contains four representations. To obtain a correct result in this case, we must therefore double the right-hand members of the equations (a), (b), (c), and (A).

If $\frac{1}{k_n^{1+\rho}}$ be the nth term of the series $\Sigma\frac{1}{(ax^2+2bxy+cy^2)^{1+\rho}}$, in which we suppose that the terms are so arranged that no term surpasses any that precedes it, it can be shown that $\lim\frac{n}{k_n}=\frac{\pi\psi(2\Delta)}{2\Delta\sqrt{\Delta}}$. For if $2\Delta\xi+\xi_0$, $2\Delta\eta+\eta_0$ represent generally any one of the $2\Delta\psi(2\Delta)$ systems of values that can be attributed to x and y consistently with the condition that (a, b, c) assumes a value prime to 2Δ, the number of terms up to k_n inclusive (*i. e.* the number n) is evidently equal to the number of points having coordinates of any one of the forms $[2\Delta\xi+\xi_0,\ 2\Delta\eta+\eta_0]$ that lie within the ellipse $ax^2+2bxy+cy^2=k_n$, together with one, or all, or some of the similar points lying on the contour of the ellipse, according as $\frac{1}{k_n^{1+\rho}}$ is the first or the last, or neither the first nor the last of the terms equal to it in the series. The area of the ellipse is $\frac{\pi k_n}{\sqrt{\Delta}}$; whence, if n be very great, the number of the points we have defined is approximately $\frac{2\Delta\psi(2\Delta)\pi k_n}{4\Delta^2\sqrt{\Delta}}$, the error being of the same order as $\sqrt{k_n}$; *i. e.*

$$\lim\frac{n}{k_n}=\frac{\pi\psi(2\Delta)}{2\Delta\sqrt{\Delta}}.$$

Hence by Dirichlet's first Lemma (art. 99) $\lim\rho S=\frac{\pi\psi(2\Delta)}{2\Delta\sqrt{\Delta}}h$. Again, by the same Lemma, the expression $\rho\Sigma\frac{1}{n^{1+\rho}}$ has $\frac{\psi(2\Delta)}{2\Delta}$ for its limit, when ρ diminishes without limit. And, lastly, the limit of the series $\Sigma\left(\frac{D}{n}\right)\frac{1}{n^{1+\rho}}$ is the series $\Sigma\left(\frac{D}{n}\right)\frac{1}{n}$, in which the terms are taken in their natural order. To establish this, we observe that the symbol $\left(\frac{D}{n}\right)$ is a periodic function of n, and that the sum of the terms of which one of its periods is composed is zero. Using the notation of art. 98, and attributing the value $+1$ or -1 to the symbol δ according as $P\equiv 1$ or $\equiv 3$, mod 4, and to the symbol ϵ according as $D=PS^2$ or $=2PS^2$, we have, by Jacobi's law of reciprocity,

$$\left(\frac{D}{n}\right)=\delta^{\frac{n-1}{2}}\epsilon^{\frac{n^2-1}{8}}\left(\frac{n}{P}\right).$$

Hence $\left(\frac{D}{n}\right)=\left(\frac{D}{n'}\right)$, if $n\equiv n'$, mod 2^kPR*; or $\left(\frac{D}{n}\right)$ is a periodic function of n.

Again, if a and b denote the general terms of a system of residues prime to 2^k and p respectively, we find

$$\Sigma\delta^{\frac{n-1}{2}}\epsilon^{\frac{n^2-1}{8}}\left(\frac{n}{P}\right)=\Sigma\delta^{\frac{a-1}{2}}\epsilon^{\frac{a^2-1}{8}}\times\Pi\,.\,\Sigma\left(\frac{b}{p}\right)\times\Pi(r-1),$$

where in the left-hand member the summation extends to every value of n prime to 2^kPQ and less than it, while in the right-hand member the signs of summation refer to a and b, and the signs of multiplication to p and r respec-

* The index k is not the same as in art. 98; it is 1 when $\delta=1$, $\epsilon=1$; 2 when $\delta=-1$, $\epsilon=1$; and 3 when $\epsilon=-1$.

tively. This equation is easily verified; for if $n \equiv a$, mod 2^k, $\equiv b$, mod p, $\equiv b'$, mod p', ... we have

$$\delta^{\frac{n-1}{2}} \epsilon^{\frac{n^2-1}{8}} \left(\frac{n}{P}\right) = \delta^{\frac{a-1}{2}} \epsilon^{\frac{a^2-1}{8}} \left(\frac{b}{p}\right)\left(\frac{b'}{p'}\right) \ldots;$$

so that each member of the equation consists of the same units. But one at least of the factors of which the right-hand member is composed is zero; unless we have simultaneously $\delta=1$, $\epsilon=1$, $P=1$, a supposition which is inadmissible, because it implies that D is a perfect square. We infer therefore that $\Sigma\left(\frac{D}{n}\right)=0$, *i. e.* that the sum of the terms of a period of the symbol $\left(\frac{D}{n}\right)$ is equal to zero. If, then, we suppose the terms of the series $\Sigma\left(\frac{D}{n}\right)\frac{1}{n^{1+\rho}}$ to be taken in their natural order, it will follow from Dirichlet's second Lemma (art. 99) that its sum represents a finite and continuous function of ρ for all values of ρ superior to -1; *i. e.* the limit of the series $\Sigma\left(\frac{D}{n}\right)\frac{1}{n^{1+\rho}}$, for $\rho=0$ is the series $\Sigma\left(\frac{D}{n}\right)\frac{1}{n}$, in which the terms are taken in their natural order. We thus obtain the equation

$$h=\frac{2\sqrt{\Delta}}{\pi}\Sigma\left(\frac{D}{n}\right)\frac{1}{n} \quad \ldots\ldots\ldots \quad (A)$$

Secondly, let the determinant D be positive; and let us retain the same notation as in the former case. If in the series

$$S=\Sigma_1\frac{1}{(a_1x^2+2b_1xy+c_1y^2)^s}+\Sigma_2\frac{1}{(a_2x^2+2b_2xy+c_2y^2)^s}$$
$$+\ldots\ldots+\Sigma_h\frac{1}{(a_hx^2+2b_hxy+c_hy^2)^s}$$

(in which it is convenient to suppose that the forms (a_k, b_k, c_k), representing the properly primitive classes of determinant D, have their first coefficients positive, and their last coefficients negative) we suppose the sign of double summation Σ_k to extend only to those integral values of x and y which render the value of the form (a_k, b_k, c_k) prime to 2D, and which further satisfy the inequalities

$$x>0,\ y>0,\ y\leqq\frac{a_kU}{T-b_kU}x,$$

we obtain, by a comparison of arts. 87 and 100, the equation

$$S=\Sigma\frac{1}{n^s}\Sigma\left(\frac{D}{n}\right)\frac{1}{n^s}; \quad \ldots\ldots\ldots \quad (c')$$

in which n denotes any positive number prime to 2D, and which corresponds to equation (c).

If $\frac{1}{k_n^{1+\rho}}$ be the nth term of the series $\Sigma\frac{1}{(ax^2+2bxy+cy^2)^{1+\rho}}$, n is equal to the number of points having coordinates of any one of the forms

$$[2\Delta\xi+\xi_0,\ 2\Delta\eta+\eta_0],$$

which lie in the interior of the sectorial area, bounded by the positive axis of x, the arc of the hyperbola $ax^2+2bxy+cy^2=k_n$, and the straight line

$$y=\frac{a\mathrm{U}}{\mathrm{T}-b\mathrm{U}}x;$$

together with one, all, or some of the similar points on the contour of the sector. The area of the sector is

$$\frac{k_n^{\pi}}{2\sqrt{\mathrm{D}}}\log(\mathrm{T}+\mathrm{U}\sqrt{\mathrm{D}});$$

whence, reasoning as before, we find

$$h=\frac{2\sqrt{\mathrm{D}}}{\log[\mathrm{T}+\mathrm{U}\sqrt{\mathrm{D}}]}\Sigma\left(\frac{\mathrm{D}}{n}\right)\frac{1}{n} \quad \ldots\ldots \quad (\mathrm{B})$$

for the number of properly primitive forms of a positive determinant D. The corresponding formulæ for improperly primitive forms are obtained by a precisely equivalent process. The results are, if $\mathrm{D}=-\Delta$,

$$\left[2-(-1)^{\frac{\mathrm{D}^2-1}{8}}\right]h'=\frac{2}{\pi}\sqrt{\Delta}\Sigma\left(\frac{\mathrm{D}}{n}\right)\frac{1}{n}*, \quad \ldots\ldots \quad (\mathrm{C})$$

and if $\mathrm{D}=+\Delta$,

$$\left[2-(-1)^{\frac{\mathrm{D}^2-1}{8}}\right]h'=\frac{2\sqrt{\mathrm{D}}}{\log\frac{1}{2}(\mathrm{T}'+\mathrm{U}'\sqrt{\mathrm{D}})}\Sigma\left(\frac{\mathrm{D}}{n}\right)\frac{1}{n}, \quad \ldots\ldots \quad (\mathrm{D})$$

$[\mathrm{T}', \mathrm{U}']$ denoting the least solution of the equation $\mathrm{T}^2-\mathrm{DU}^2=4$.

102. *Proof that each Genus contains the same number of Classes.*—The sixth section of the memoir also contains a demonstration of the proposition to which we have already referred (art. 98), that all the possible genera actually exist, and contain an equal number of classes. This demonstration is not deduced from the expression for the number of properly primitive forms, but depends on an equation between two infinite series similar to the equation (a) of the last article. Let χ denote any one of the particular characters proper to the determinant, and let ϕ be any term in the product $\Pi(1+\chi)$, with the exception of the first term, which is unity, and also of that particular combination of the values of χ, the value of which, by the condition of possibility, is also a positive unit. If λ be the number of particular characters, $2^\lambda-2$ will be the number of expressions symbolized by ϕ. Let H and H′ be the numbers of classes satisfying the conditions $\phi=1$ and $\phi=-1$ respectively. It can be shown, as follows, that $\mathrm{H}=\mathrm{H}'$. Confining ourselves, for perspicuity, to the case of forms of a negative determinant, we have, by the principle of art. 87,

$$\Sigma_1\frac{\phi_1}{(a_1x^2+2b_1xy+c_1y^2)^s}+\Sigma_2\frac{\phi_2}{(a_2x^2+2b_2xy+c_2y^2)^s}+\ldots$$
$$+\Sigma_h\frac{\phi_h}{(a_hx^2+2b_hxy+c_h)^s}=2\Sigma\left[\Sigma\left(\frac{\mathrm{D}}{d}\right)\right]\left(\frac{\phi}{n}\right)\frac{1}{n^s}, \quad \ldots\ldots \quad (d)$$

where in the right-hand member $\left(\frac{\phi}{n}\right)$ is $+1$ or -1, according as the number n satisfies the condition $\phi=1$ or $\phi=-1$; and similarly, in the left-hand member $\phi_k=-1$ or $=+1$, according as the generic character of the form (a_k, b_k, c_k) satisfies the condition $\phi=1$ or $\phi=-1$. In this equation the

* If $\Delta=3$, we must triple the right-hand member of this equation; as each set of representations of a number by a form of determinant -3 contains six representations, instead of two.

signs of summation have the same signification as in the similar equation (a) of the last article; and, as in that equation, the right-hand member may be expressed in the simpler form

$$\Sigma\left(\frac{\phi}{n}\right)\frac{1}{n^s}\,\Sigma\left(\frac{D}{n}\right)\left(\frac{\phi}{n}\right)\frac{1}{n^s}.$$

If we now write $1+\rho$ for s, and, multiplying by ρ, allow ρ to converge to zero, the limit of the left-hand number is $(H-H')\dfrac{\pi\psi(2\Delta)}{2\Delta\sqrt{\Delta}}$. The series $\Sigma\left(\frac{D}{n}\right)\left(\frac{\phi}{n}\right)\frac{1}{n^{1+\rho}}$ converges to a finite limit; for $\left(\frac{D}{n}\right)$ and $\left(\frac{\phi}{n}\right)$ are each of them expressions of the form $\delta^{\frac{n-1}{2}}\epsilon^{\frac{n^2-1}{8}}\left(\frac{n}{Q}\right)$, δ and ϵ denoting positive or negative units, and Q an uneven number composed of unequal primes dividing D; their product is therefore another expression of the same form, in which δ, ϵ and Q are not simultaneously equal to 1, because we have expressly excluded that combination of the particular characters which causes $\left(\frac{\phi}{n}\right)$ to coincide with $\left(\frac{D}{n}\right)$. It can therefore be shown, by reasoning as in the last article, that the second Lemma of art. 99 is applicable to the series, and that it converges to the finite limit $\Sigma\left(\frac{D}{n}\right)\left(\frac{\phi}{n}\right)\frac{1}{n}$. Similarly, it may be shown that $\Sigma\left(\frac{\phi}{n}\right)\frac{1}{n^{1+\rho}}$ converges to a finite limit. The limit of the right-hand member of the equation (d) is consequently zero on account of the evanescent factor ρ; from which it follows that $H=H'$. Let $G_1, G_2, \ldots$ be the different possible genera; $h_1, h_2, \ldots$ the number of classes they severally contain; $\left(\frac{\phi}{G}\right)$ the value of ϕ for the genus G. The equation $H-H'=0$ comprises $2^\lambda-2$ equations of the type

$$\left(\frac{\phi}{G_1}\right)h_1+\left(\frac{\phi}{G_2}\right)h_2+\ldots=0,$$

corresponding to the $2^\lambda-2$ different expressions symbolized by ϕ. If we multiply each of these equations by the coefficient of h_k in it, and add the products to the equation

$$2h_1+2h_2+2h_3+\ldots=2h,$$

we arrive at the conclusion $2^\lambda h_k=2h$. For the coefficient of h_r in the resulting equation is the product $\Pi\left[1+\left(\frac{\chi}{G_r}\right)\left(\frac{\chi}{G_k}\right)\right]$; and this product is 2^λ, if G_r and G_k are identical, but is zero in every other case, as one at least of the factors will be zero.

103. The seventh section (Crelle, vol. xxi. p. 1) commences with the proof of the theorem that the number of sets of representations of any number M prime to 2D by quadratic forms of determinant D, is equal to the excess of the number of those divisors d of M which satisfy the equation

$$\delta^{\frac{d-1}{2}}\epsilon^{\frac{d^2-1}{8}}\left(\frac{d}{P}\right)=1,$$

above the number of those divisors which satisfy the equation

$$\delta^{\frac{d-1}{2}}\epsilon^{\frac{d^2-1}{2}}\left(\frac{d}{P}\right)=-1,$$

the symbols δ and ϵ having the same signification as in art. 101. Of this theorem, which coincides with that of art. 87, since

$$\left(\frac{D}{d}\right)=\delta^{\frac{d-1}{2}}\epsilon^{\frac{d^2-1}{2}}\left(\frac{d}{P}\right),$$

two demonstrations are given, one purely arithmetical, the other derived from the equation (b) of art. 101, the proof of which in Dirichlet's memoir does not involve the theorem of art. 87, but is deduced from the arithmetical principles on which that theorem itself depends. We have already referred (art. 95) to some of the particular results which can be deduced from the general theorem.

It is evident from the mode of formation of the equation (b), or of the corresponding equation for a positive determinant, that it may be generalized by taking instead of the power $(ax^2+2bxy+cy)^{-s}$, any function of $ax^2+2bxy+cy^2$ which renders the two members of the equation convergent; *i.e.* we may write, in the case of a negative determinant,

$$\Sigma_1 \,.\, \phi(a_1x^2+2b_1xy+c_1y^2)+\Sigma_2 \,.\, \phi(a_2x^2+2b_2xy+c_2y^2)+\ldots$$
$$=2\Sigma\left(\frac{D}{n}\right)\phi(nn').$$

Dirichlet illustrates this observation by giving to ϕ the exponential form q^z, which satisfies the condition of convergence, if the analytical modulus of q be inferior to unity. Each double sum, such as $\Sigma q^{ax^2+2bxy+cy^2}$ in the left-hand member of the equation

$$\Sigma_1 q^{a_1x^2+2b_1xy+c_1y^2}+\Sigma_2 q^{a_2x^2+2b_2xy+c_2y^2}+\ldots$$
$$=2\Sigma\left(\frac{D}{n}\right)q^{nn'},$$

can then be replaced by $2a\Delta\psi(2\Delta)$ (or sometimes by fewer) products of the form

$$\sum_{v=-\infty}^{v=\infty} q^{\frac{1}{a}(2a\Delta v+v_0)^2}\times\sum_{v=-\infty}^{v=\infty} q^{\frac{\Delta}{a}(2a\Delta v+v_1)^2},$$

in which each simple series such as

$$\sum_{v=-\infty}^{v=\infty} q^{\frac{1}{a}(2a\Delta v+v_0)^2}$$

can be expressed by means of the elliptic function Θ; the right-hand member can also be expressed by means of elliptic series. If, for example, $D=-3$, we have the equation

$$\sum_{v=-\infty}^{v=\infty} q^{(6v+1)^2}\times\sum_{v=-\infty}^{v=+\infty} q^{3\cdot(2v)^2}+\sum_{v=-\infty}^{v=+\infty} q^{(6v+2)^2}\times\sum_{v=-\infty}^{v=\infty} q^{3(2v+1)^2}$$
$$=\sum_{k=0}^{k=\infty}\frac{q^{6k+1}+q^{5(6k+1)}}{1-q^{6(6k+1)}}-\sum_{k=0}^{k=\infty}\frac{q^{6k+5}+q^{5(6k+5)}}{1-q^{6(6k+5)}}.$$

It does not appear that this remarkable transformation, which is only very briefly noticed by Dirichlet, has been further examined. (See a note by Mr. Cayley in the Cambridge and Dublin Mathematical Journal, vol. ix. p. 163.)

In the eighth section Dirichlet assigns the relation between the numbers of properly and improperly primitive classes. When the determinant is negative we find, by a comparison of the formulæ (A) and (C), $h=h'$, or $h=3h'$, according as $D\equiv 1$, or $\equiv 5$, mod 8; observing only that if $D=-3$ we have, exceptionally, $h=h'$. When the determinant is positive, we infer from the formulæ (B) and (D),

$$h=\frac{\log\frac{1}{2}(T'+U'\sqrt{D})}{\log(T+U\sqrt{D})}h',$$

$$\text{or } h=\frac{3\log\frac{1}{2}(T'+U'\sqrt{D})}{\log(T+U\sqrt{D})}h',$$

according as $D\equiv 1$ or $\equiv 5$, mod 8. Comparing these expressions with the observations in art. 96 (vi.), we find, if $D\equiv 1$, mod 8, $h=h'$; and if $D\equiv 5$, mod 8, $h=h'$, or $h=3h'$, according as the least solution of the equation $T^2-DU^2=4$ is uneven or even.

Dirichlet also deduces from the formulæ (A) and (B) the relation which subsists between the numbers of properly primitive classes for any two determinants which are to one another as two square numbers. It is sufficient to consider two determinants such as D and DS^2, of which the former is not divisible by any square. If h and H be the numbers of classes for these two determinants, we have evidently, when the determinants are negative,

$$\frac{H}{h}=S\frac{\Sigma\left(\frac{D}{n}\right)\frac{1}{n}}{\Sigma\left(\frac{D}{n}\right)\frac{1}{n}};$$

the two series in the numerator and denominator not being identical, because in the one n is any number prime to $2DS^2$, in the other any number prime to 2D. But, by a principle due to Euler,

$$\Sigma\left(\frac{D}{n}\right)\frac{1}{n}=\Pi\frac{1}{1-\left(\frac{D}{p}\right)\frac{1}{p}},$$

p representing any prime, except those dividing $2DS^2$ or 2D. Hence

$$H=hS\Pi\left(1-\left(\frac{D}{s}\right)\frac{1}{s}\right),$$

if s denote any prime dividing S but not dividing D. For a positive determinant we find

$$H=hS\Pi\left(1-\left(\frac{D}{s}\right)\right)\frac{\log(T+U\sqrt{D})}{\log(T'+U'\sqrt{D})},$$

[T′, U′] denoting the least solution of the equation $T^2-DS^2U^2=1$; *i.e.* the least solution $[T_k, U_k]$ of $T^2-DU^2=1$, which satisfies the condition $U_k\equiv 0$, mod S; so that we may write

$$H=h\frac{S}{k}\Pi\left(1-\left(\frac{D}{s}\right)\frac{1}{s}\right).$$

In a subsequent note (No. 7 in the list) Dirichlet infers from this expression that, given any positive determinant D, we can always deduce from it an infinite number of determinants of the form DS^2 having all the same numbers of classes. For if we attribute to S a series of values of the form $\Pi.s^\alpha$, all composed of the same prime numbers s, and having continually increasing numbers for the indices of those primes, it appears from a remark to which we have already referred (see art. 96, v.), that the quotient $\frac{S}{k}$ will eventually be constant; *i. e.* there will exist an infinite series of determinants, all composed of the same primes, and all having the same number of properly primitive classes. As it is possible to find determinants contained in a series of this kind, and having only one class in each genus, it appears that the number of the positive determinants, which have only one class in each genus, is infinite. This result, which was anticipated by Gauss (Disq. Arith. art. 304), is remarkable, because it is probable, from the result of a very extensive induction, that there are but 65 negative determinants, of which the greatest is -1848, having the same property.

104. *Summation of the series expressing the number of Properly Primitive Classes.*—It appears from the last article that, to obtain expressions in a finite form for the number of classes, we may confine our attention to the order of properly primitive forms, and may suppose that the determinant is not divisible by any square. To sum the series $\Sigma\left(\frac{D}{n}\right)\frac{1}{n}$ upon this supposition, Dirichlet employs the formulæ given by Gauss in his memoir, "Summatio Serierum quarundam singularium," to which we have already referred in this Report (art. 20). The ninth section is occupied with the demonstration of these formulæ; in the tenth they are applied to the summation of the series $\Sigma\left(\frac{D}{n}\right)\frac{1}{n}$. Two different methods are given by Dirichlet, by either of which this summation can be effected.

(i.) If k be the index of periodicity of $\left(\frac{D}{n}\right)$, so that $\left(\frac{D}{n+k}\right)=\left(\frac{D}{n}\right)$, and $\sum_1^k\left(\frac{D}{n}\right)=0$, the summation indicated by the symbol $\sum_1^k$ extending to all values of n prime to 2D from 1 to k, we have, writing V for $\Sigma\left(\frac{D}{n}\right)\frac{1}{n}$,

$$V=-\int_0^1\frac{\frac{1}{x}f(x)}{x^k-1}\,dx,$$

where $f(x)=\sum_1^k\left(\frac{D}{n}\right)x^n$, so that $f(1)=0$. Integrating by the ordinary method of decomposition into partial fractions, we find

$$-kV=\sum_{m=1}^{m=k-1} f\left(\epsilon^{\frac{2m\pi}{k}i}\right)\int_0^1\frac{dx}{x-\epsilon^{\frac{2m\pi}{k}i}}$$

$$=\sum_{m=1}^{m=k-1} f\left(\epsilon^{\frac{2m\pi i}{k}}\right)\left[\log\left(2\sin\frac{m\pi}{k}\right)+i\frac{\pi}{2}\left(1-\frac{2m}{k}\right)\right].$$

To simplify this complicated expression, it is requisite to transform the symbol $\left(\frac{D}{n}\right)$ by the law of reciprocity, and to consider separately the eight cases which arise from every possible combination of the hypotheses (α) D positive or negative, (β) D even or uneven, (γ) D, or $\frac{1}{2}$D, $\equiv 1$, mod 4, or $\equiv 3$, mod 4. As an example of the process, we shall take the two cases in which $D \equiv 3$, mod 4, so that $\left(\frac{D}{n}\right)=(-1)^{\frac{n-1}{2}}\left(\frac{n}{\Delta}\right)$, $k=4\Delta$, Δ still denoting the absolute value of D. The value of $f\left(\epsilon^{\frac{2m\pi}{4\Delta}i}\right)$ is assigned by the formulæ of Gauss; it is $2i^{\frac{1}{4}(1+\Delta)^2}(-1)^{\frac{m-1}{2}}\left(\frac{m}{\Delta}\right)\sqrt{\Delta}$, or zero, according as m is, or is not, prime to 4Δ*. We thus find

$$-4\Delta V=2i^{\frac{1}{4}(1+\Delta)^2}\sqrt{\Delta}\Sigma(-1)^{\frac{m-1}{2}}\left(\frac{m}{\Delta}\right)\left[\log\left(2\sin\frac{m\pi}{4\Delta}\right)+\frac{\pi}{2}i\left(1-\frac{m}{2\Delta}\right)\right],$$

the summation extending to all values of m prime to 4Δ and less than it. In

* If p be any prime divisor of Δ, an uneven number admitting of no square divisor, and if, for brevity, $P=\frac{\Delta}{p}$; we have, by Gauss's formula,

$$\sum_{k=1}^{k=p-1}\left(\frac{k}{p}\right)\epsilon^{\frac{2kmP\pi}{p}i}=\left(\frac{m}{p}\right)\left(\frac{P}{p}\right)i^{\frac{1}{4}(p-1)^2}\sqrt{p}, \text{ or } =0, \quad . \quad . \quad . \quad . \quad (1)$$

according as m is or is not prime to p. If we multiply together the equations of this type, corresponding to every prime divisor of Δ, and observe (1) that $\theta=\Sigma\,.\,kP^2$ represents a system of residues prime to Δ, (2) that $\left(\frac{\theta}{\Delta}\right)=\left(\frac{\theta}{p_1}\right)\left(\frac{\theta}{p_2}\right)\ldots=\left(\frac{k_1}{p_1}\right)\left(\frac{k_2}{p_2}\right)\ldots$, (3) that

$$\Pi\left(\frac{P}{p}\right)i^{\frac{1}{4}(p-1)^2}=(-1)^{\Sigma\frac{1}{4}(p_1-1)(p_2-1)}i^{\Sigma\frac{1}{4}(p-1)^2}=i^{\frac{1}{4}[\Sigma(p-1)]^2}=i^{\frac{1}{4}(\Delta-1)^2}, \text{ we find}$$

$$\Sigma\left(\frac{\theta}{\Delta}\right)\epsilon^{\frac{2\theta m\pi}{\Delta}i}=\left(\frac{m}{\Delta}\right)i^{\frac{1}{4}(\Delta-1)^2}\sqrt{\Delta}, \text{ or } =0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

according as m is or is not prime to Δ. We have already met with this equation in art. 96, ix. If in the equations (1) we write 4P for P, and join to them the equation

$$\Sigma(-1)^{\frac{k-1}{2}}\epsilon^{\frac{2km\Delta\pi}{4}i}=2i(-1)^{\frac{m-1}{2}+\frac{\Delta-1}{2}}, \ (m \text{ uneven}), \text{ or } =0 \ (m \text{ even}),$$

in which k is either term of a system of residues prime to 4, we obtain after multiplication the equation which is employed in the text. And similarly may the function $f\left(\epsilon^{\frac{2mn}{k}i}\right)$ be evaluated, whatever be the form of D.

The formulæ (A) and (A′) of art. 20 are only particular cases of the general result obtained by Gauss in the 'Summatio Serierum, &c.' The general formula, including (A), is $\sum_{k=0}^{k=n-1} r^{hk^2}=\left(\frac{h}{n}\right)i^{\frac{1}{4}(n-1)^2}\sqrt{n}$, h denoting any number prime to n. When n is even, the formula (A′) of art. 20 is similarly included in the following,

$$\Sigma r^{hk^2}=0, \text{ or } =\left(\frac{n}{h}\right)i^{-\left(\frac{h-1}{2}\right)^2}(1+i)\sqrt{n},$$

according as n is unevenly or evenly even.

When n is uneven and not divisible by any square, the two sums

$$\sum_{k=0}^{k=n-1} r^{hk^2} \text{ and } \Sigma\left(\frac{\theta}{n}\right)r^{h\theta}$$

are identical, as appears from a comparison of (2) with the generalization of (A), and as has been already observed in the case when n is a prime (art. 21).

this expression the sum $\Sigma(-1)^{\frac{m-1}{2}}\left(\frac{m}{\Delta}\right)$ is zero, because the terms corresponding to m and $2\Delta+m$ destroy one another; so that

$$-4\Delta V=2i^{\frac{1}{4}(1+\Delta)^2}\sqrt{\Delta}\,\Sigma(-1)^{\frac{m-1}{2}}\left(\frac{m}{\Delta}\right)\left[\log\left(\sin\frac{m\pi}{4\Delta}\right)-i\frac{m\pi}{4\Delta}\right].$$

Distinguishing the two cases $D=\Delta$, and $D=-\Delta$, and observing that the imaginary parts vanish identically, as they ought to do, because V is real, we have, finally, if $D=\Delta$,

$$-4DV=2\sqrt{D}\,\Sigma(-1)^{\frac{m-1}{2}}\left(\frac{m}{D}\right)\log\sin\left(\frac{m\pi}{4D}\right)$$

$$=2\sqrt{D}\,\Sigma\left(\frac{D}{m}\right)\log\sin\frac{m\pi}{4D};$$

and if $D=-\Delta$,

$$-4\Delta V=\frac{\pi}{2\sqrt{\Delta}}\Sigma(-1)^{\frac{m-1}{2}}\left(\frac{m}{\Delta}\right)m$$

$$=\frac{\pi}{2\sqrt{\Delta}}\Sigma\left(\frac{D}{m}\right)m.$$

(ii.) The series $\Sigma\left(\frac{D}{n}\right)\frac{1}{n}$ can also be summed by substituting for $\left(\frac{D}{n}\right)$ its trigonometrical value deducible from the formulæ of Gauss. We will take as an example the case in which $D=-\Delta\equiv 3$, mod 4. Writing n for m, and m for n, in the equation

$$f\left(\epsilon^{\frac{2m\pi}{4\Delta}i}\right)=2i^{\frac{1}{4}(1+\Delta)^2}(-1)^{\frac{m-1}{2}}\left(\frac{m}{\Delta}\right)\sqrt{\Delta},$$

we find, observing that $\frac{1}{2}(1+\Delta)$ is uneven,

$$\left(\frac{D}{n}\right)=(-1)^{\frac{n-1}{2}}\left(\frac{n}{\Delta}\right)=\frac{1}{2i\sqrt{\Delta}}\Sigma\left(\frac{D}{m}\right)\epsilon^{\frac{2mn\pi}{4\Delta}i}$$

$$=\frac{1}{2\sqrt{\Delta}}\Sigma\left(\frac{D}{m}\right)\sin\left(\frac{2mn\pi}{4\Delta}\right),$$

the summation extending to every value of m prime to 4Δ and less than it. Substituting this expression for $\left(\frac{D}{n}\right)$ in V, we have

$$V=\frac{1}{2\sqrt{\Delta}}\Sigma\left(\frac{D}{m}\right)\Sigma\frac{1}{n}\sin\left(\frac{2mn\pi}{4\Delta}\right).$$

Since the expression which we have substituted for $\left(\frac{D}{n}\right)$ is zero, when n is not prime to 4Δ, we may attribute to n, in the series

$$\Sigma\frac{1}{n}\sin\left(\frac{2mn\pi}{4\Delta}\right),$$

either all uneven values, or all integral values. The sum of the series

$$\frac{\sin x}{1}+\frac{\sin 3x}{3}+\frac{\sin 5x}{5}+\dots$$

is, by a known theorem, $\frac{\pi}{4}$ or $-\frac{\pi}{4}$, according as $0<x<\pi$, or $\pi<x<2\pi$. Hence attributing to n only uneven values, and denoting by m' and m'' the values of m inferior and superior to 2Δ,

$$V=\frac{\pi}{8\sqrt{\Delta}}\Sigma\left[\left(\frac{D}{m'}\right)-\left(\frac{D}{m''}\right)\right]$$

$$=\frac{\pi}{4\sqrt{\Delta}}\Sigma\left(\frac{D}{m'}\right),$$

because $\left(\frac{D}{m'}\right)=-\left(\frac{D}{2\Delta+m'}\right)$.

If we attribute to n all integral values, the equation

$$\frac{1}{2}(\pi-x)=\frac{\sin x}{1}+\frac{\sin 2x}{2}+\frac{\sin 3x}{3}+\ldots,$$

which subsists for all positive values of x less than 2π, will give the value already obtained for V by the former method, viz.,

$$-4\Delta V=\frac{\pi}{2\sqrt{\Delta}}\Sigma\left(\frac{D}{m}\right)m.$$

The mode of application of this method may be still further varied; for, instead of substituting for $(-1)^{\frac{n-1}{2}}\left(\frac{n}{\Delta}\right)$, we may leave the factor $(-1)^{\frac{n-1}{2}}$ unchanged, and substitute for $\left(\frac{n}{\Delta}\right)$, by means of the equation

$$\left(\frac{n}{\Delta}\right)=\frac{1}{\sqrt{\Delta}}\Sigma\left(\frac{m}{\Delta}\right)\cos\left(\frac{2mn\pi}{\Delta}\right),$$

which, as well as the substitution which we have employed, is deducible from the formulæ of Gauss*. We should thus obtain a third expression for V, different in form from both of those which we have already found.

The forms which the expression of h can assume are very numerous; we select the following as examples, D still denoting a determinant not divisible by any square.

I. If $D\equiv 1$, mod 4.

For a positive determinant, $D=\Delta$,

$$h=\left(\frac{2}{D}\right)\frac{2}{\log(T+U\sqrt{D})}\Sigma\left(\frac{D}{m}\right)\log\tan\left(\frac{m\pi}{2D}\right).$$

For a negative determinant $D=-\Delta$,

$$h=-\left(\frac{2}{\Delta}\right)\Sigma\left(\frac{D}{m}\right),$$

the summations extending to every uneven value of m prime to Δ and less than Δ.

II. If D be not $\equiv 1$, mod 4.

For a positive determinant,

$$h=-\frac{1}{\log(T+U\sqrt{D})}\Sigma\left(\frac{D}{m}\right)\log\sin\left(\frac{m\pi}{4D}\right).$$

* See equation (2) of the preceding note.

For a negative determinant,

$$h=-\frac{1}{4\Delta}\Sigma\left(\frac{D}{m}\right)m=+\frac{1}{2}\Sigma\left(\frac{D}{m'}\right),$$

the summations with respect to m and m' extending to all values prime to 2Δ, and inferior to 4Δ and 2Δ respectively.

Dirichlet observes that when the determinant is positive, the coefficient of $\frac{1}{\log(T+U\sqrt{D})}$ is a logarithm of the form $\log(T_h+U_h\sqrt{D})$; (T_h, U_h) being one of those solutions of the equation $T^2-DU^2=1$ which are deducible from the theory of the division of the circle. Thus h is in fact determined as the index of the place occupied in the series of solutions of $T^2-DU^2=1$, by an assigned trigonometrical solution. (See a note by M. Arndt in Crelle, vol. lvi. p. 100.)

In the particular case in which the determinant is a prime of the form $4n+3$ taken negatively, an expression for the number of classes had already been given by Jacobi (Crelle, vol. ix. p. 189). It would seem, from his note on the division of the circle (Crelle, vol. xxx. p. 166), that the unpublished method, by which his result was obtained, formed a part of that theory.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

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MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

MATHEMATICS AND PHYSICS.

Mathematics.

Address by G. B. Airy, *M.A., F.R.S., Astronomer Royal, President of the Section.*

The President said it was usual, in opening the proceedings of this Section, to commence with a few words, stating generally the object for which they were met, and the way in which they proposed to carry it out. That Section was one which dealt with Mathematics and Natural Philosophy, and under these heads they included everything which was not of a technical nature, and which was the subject of mathematical treatment. Everything which was reducible to measures or forces came properly under their consideration, if it were not expressly a subject belonging to some technical Section. Cosmology, or the changes which the world has undergone, came properly before them; and that Section might be considered as dealing with the germs of all the sciences which were subjects of measure or number. Its subjects might be compared with those which most of our Universities made the foundation for the important degree of Arts, and which are understood to be the best foundation of education possible to provide for the human mind. It was to those subjects that the early efforts of the Association were directed, and in a great measure it was those subjects that had enabled the Association to acquire its present importance. It was well known to members of that Association that its earliest efforts were directed to astronomy; almost the earliest expenditure of money by the Association was in reference to astronomy, and the works the Association had published at its own expense had been amongst the most valuable contributions to that science. By the expenditure, of money in that way, the Association had acquired a command over the Government which had enabled it to call for assistance in very important matters. The reduction of the lunar observations at the Royal Observatory at Greenwich was undertaken in consequence of the urgency of the representations made by the British Association, and anybody who knew the history of science would admit that that great work was one of the most important services that had been rendered to astronomy. There were other subjects to which benefit had been derived from the representations of the Association, amongst which he might mention the great magnetic expeditions under the direction of Major-General Sabine. These expeditions, which had been effected at the expense of the Government, had made us acquainted with magnetism all over the earth, and had given us information such as we could not have got in any other way. In speaking thus of the importance of these subjects, and of their proper connexion with that Section, he had only to say that they should be happy to receive any communication bearing upon similar subjects. In dealing with them, it was desirable in all cases that they should consider themselves as treating questions strictly of science. In the next place, he hoped that those who made communications would bear in mind that their time was to be used, and not wasted. It was desirable that nothing should be brought before the Meeting that would not be understood, *ipso facto*, from the reading of the paper or oral communication, by the majority of the persons present. There was no use in gentlemen bringing complicated technical papers which could not be understood without a month's study of a printed book. In the next place, recapitulations of what had been done before ought to be as brief as possible. And whilst he hoped that the papers would be well discussed, he trusted that personality of every kind would be strictly eschewed. It was known to those present that great ingenuity had been employed upon certain abstract propositions of mathematics which had been rejected by the learned in all ages, such as finding the length of the circle, and perpetual motion. In the best academies of Europe, it was established as a rule that subjects of that kind should not be admitted, and it was desirable that such communications should not be made to that Section, as they were a mere loss of time.

The President then stated that at the last meeting Professor Stokes was requested to make a report, at the instance of the Committee of that Section, on "The present state of Physical Optics." He had written to say that he had been prevented by a great quantity of public business from preparing a report in time for that meeting, but he engaged to prepare it in time for the next meeting of the Association, and the Committee had requested him to do so. He had to make a similar explanation with reference to a report that had been promised by Mr. Cayley on the solution of specific problems of dynamics. The Committee had requested him to prepare his report in time for the next meeting of the Society.

On Curves of the Third Order. *By* A. Cayley, *F.R.S.*

A curve of the third order, or cubic curve, is the section of a cubic cone, and such cone is intersected by a concentric sphere in a spherical cubic. It is an obvious consequence of a theorem of Sir Isaac Newton's, that there are five principal kinds of cubic cones, or, what is the same thing, five principal kinds of spherical cubics; but the nature of these five kinds of spherical cubics was first distinctly explained by Möbius. They may be designated the *simplex*, the *complex*, the *crunodal*, the *acnodal*, and the *cuspidal*; where crunode, acnode denote respectively the two species of double points (nodes), viz. the double point with two real branches, and the conjugate or isolated point. The foregoing results are known; the special object of the paper was to establish a subdivision of the simplex kind of spherical curves. The simplex kind is a continuous re-entering curve cutting a great circle (to fix the ideas say the equator) in three pairs of opposite points, which are the three real inflexions of the curve. The three great circles, which are the tangents at the inflexions, and the equator, divide the entire surface of the sphere into fourteen regions, whereof eight are trilateral, and the remaining six quadrilateral. The curve may lie entirely in six out of the eight trilateral regions, and it is in this case said to be *simplex trilateral*; or it may lie entirely in the six quadrilateral regions, and it is in this case said to be *simplex quadrilateral*: and there is an intermediate form, the *simplex neutral*; viz. in this case the three great circles, tangents to the inflexions, meet in a pair of opposite points, and there are in all only twelve regions, all trilateral; the curve lies entirely in six of these regions.

On the General Forms of the Symmetrical Properties of Plane Triangles. *By* Thomas Dobson, *B.A.*

This paper establishes among the distances from an indefinite plane of the symmetrical points connected with a plane triangle certain general relations, which yield several corresponding cognate plane properties when different definite positions are assigned to the plane of reference. In the plane triangle A B C, let O be the centre of the inscribed circle, O_1 O_2 O_3 those of the escribed circles touching BC, CA, AB; and let OO_1 cut BC in D. Denote, as usual, the radii of these circles by r r_1 r_2 r_3, the sides opposite to A, B, C by a, b, c, and $a+b+c$ by $2s$. From A, B, C, O, O_1, O_2, O_3, and D let perpendiculars $\alpha, \beta, \gamma, \delta, \delta_1, \delta_2, \delta_3$, and m be drawn to any plane.

Then, by similar triangles,

$$\frac{m-\alpha}{\delta-\alpha}=\frac{AD}{AO}=\frac{2s}{b+c}; \quad \frac{\gamma-m}{m-\beta}=\frac{CD}{BD}=\frac{b}{c}; \quad \text{and } \frac{\delta_1-\alpha}{\delta-\alpha}=\frac{AO_1}{AO}=\frac{s}{s-\alpha},$$

eliminating m, &c.,

$$2s\delta=a\alpha+b\beta+c\gamma; \qquad 2(s-a)\,\delta_1=-a\alpha+b\beta+c\gamma;$$
$$2(s-b)\,\delta_2=a\alpha-b\beta+c\gamma; \quad 2(s-c)\,\delta_3=a\alpha+b\beta-c\gamma.$$

If S be the area of the triangle ABC, and $p_1\, p_2\, p_3$ the perpendiculars from A, B, C, on a, b, c,

$$2S=ap_1=bp_2=cp_3;\ \text{and}\ S=rs=r_1(s-a)=r_2(s-b)=r_3(s-c).$$

Hence, if the plane of reference be perpendicular to the plane of the triangle, and intersect that plane in a tangent to any of the circles r, r_1, r_2, r_3, so that $\delta=r$ for instance, then $2S=a\alpha+b\beta+c\gamma$; α, β, γ having the proper algebraical signs for each case. The above equations are now readily transformed into

$$\frac{\delta}{r}=\frac{\alpha}{p_1}+\frac{\beta}{p_2}+\frac{\gamma}{p_3};\quad \frac{\delta_1}{r_1}=-\frac{\alpha}{p_1}+\frac{\beta}{p_2}+\frac{\gamma}{p_3};$$

$$\frac{\delta_2}{r_2}=\frac{\alpha}{p_1}-\frac{\beta}{p_2}+\frac{\gamma}{p_3};\quad \frac{\delta_3}{r_3}=\ \frac{\alpha}{p_1}+\frac{\beta}{p_2}-\frac{\gamma}{p_3}.$$

Whence are derived

$$\frac{\delta}{r}=\frac{\delta_1}{r_1}+\frac{\delta_2}{r_2}+\frac{\delta_3}{r_3};\quad \frac{2\alpha}{p_1}=\frac{\delta_2}{r_2}+\frac{\delta_3}{r_3};$$

$$\frac{2\beta}{p_2}=\frac{\delta_3}{r_3}+\frac{\delta_1}{r_1};\quad \frac{2\gamma}{p_3}=\frac{\delta_1}{r_1}+\frac{\delta_2}{r_2}.$$

If the plane of reference is parallel to the plane of the triangle,

$$\alpha=\beta=\gamma=\delta=\delta_1=\delta_2=\delta_3;\ \dots\dots\dots\dots\ (A)$$

and the above eight equations give corresponding plane theorems. When the ordinates are referred to the plane which is tangential to the three spheres of which the centres are O_1, O_2, O_3, and radii r_1, r_2, r_3, we have

$$\left.\begin{array}{l}\delta_1=r_1,\ \delta_2=r_2,\ \delta_3=r_3;\\ \therefore\ \delta=3r,\ \alpha=p_1,\ \beta=p_2,\ \text{and}\ \gamma=p_3\end{array}\right\}\dots\dots\dots\dots\ (B)$$

The plane (B) is therefore tangential to the seven spheres of which A, B, C, O_1, O_2, O_3, and O are the centres, and p_1, p_2, p_3, r_1, r_2, r_3, and $3r$ the radii.

Let Q be the centre of the circle circumscribing the triangle A B C, R its radius, and Δ the distance of Q from the plane of reference. Then, proceeding as before, it is found that

$$4\sin A\sin B\sin C\,.\,\Delta=\alpha\sin 2A+\beta\sin 2B+\gamma\sin 2C;$$

$$\frac{\Delta}{R}=\frac{\alpha}{p_1}\cos A+\frac{\beta}{p_2}\cos B+\frac{\gamma}{p_3}\cos C;$$

$$\tfrac{1}{2}\left(\frac{\delta}{r}+\frac{\Delta}{R}\right)=\frac{\alpha}{p_1}\cos^2\tfrac{1}{2}A+\frac{\beta}{p_2}\cos^2\tfrac{1}{2}B+\frac{\gamma}{p_3}\cos^2\tfrac{1}{2}C;$$

$$\tfrac{1}{2}\left(\frac{\delta}{r}-\frac{\Delta}{R}\right)=\frac{\alpha}{p_1}\sin^2\tfrac{1}{2}A+\frac{\beta}{p_2}\sin^2\tfrac{1}{2}B+\frac{\gamma}{p_3}\sin^2\tfrac{1}{2}C.$$

For the plane (B) the second equation gives $\Delta=R+r$.

The circumscribing circle bisects $O_2\,O_3$, $O_3\,O_1$, $O_1\,O_2$ in A′, B′, C′; and if $\alpha'\,\beta'\,\gamma'$ be for A′ B′ C′ what $\alpha\,\beta\,\gamma$ are for A B C, $2\alpha'=\delta_2+\delta_3$; also $\angle A'=\angle O_1=\frac{1}{2}(\pi-A)$. Applying the first of the above theorems to the triangle A′ B′ C′, and reducing, we get

$$4\Delta=\delta+\delta_1+\delta_2+\delta_3;$$

and if this be referred to the plane (B), we have the well-known plane theorem,

$$4R=-r+r_1+r_2+r_3.$$

Applying the same general theorem to the triangle $O_1\,O_2\,O_3$, we have $\Delta'+\delta=2\Delta$, where Δ' is for $O_1\,O_2\,O_3$ what Δ is for A B C. Also

$$\frac{\Delta'}{r}=\frac{\delta_1}{p_1}+\frac{\delta_2}{p_2}+\frac{\delta_3}{p_3};$$

if this be referred to the plane (B), for which $\Delta'=2R-r$, we get the plane theorem

$$\frac{2R}{r}=1+\frac{r_1}{p_1}+\frac{r_2}{p_2}+\frac{r_3}{p_3}.$$

Let δ' be the distance from the plane of reference of the point of intersection of

p_1, p_2, p_3; and Δ'' the distance of the centre of the circle through the feet of p_1, p_2, p_3; then by what precedes,

$$2\Delta+\delta'=\alpha+\beta+\gamma;\quad 2\Delta''=\Delta+\delta';$$
$$4\Delta''=\delta'+\alpha+\beta+\gamma;\ \text{and}$$
$$\frac{\Delta'-\delta'}{s}+\frac{\delta-\delta_1}{a}+\frac{\delta-\delta_2}{b}+\frac{\delta-\delta_3}{c}=0.$$

Let Δ_1, Δ_2, Δ_3, Δ'_1, Δ'_2, Δ'_3, be the distances from the plane of reference of the centres of the circles circumscribing the component triangles of the complete quadrilaterals of which O, O_1, O_2, O_3, are the vertical points; then

$$2\Delta_1=\delta_2+\delta_3,\ \&c.,\quad 2\Delta_1'=\delta+\delta_1,\ \&c.;$$
$$\therefore \Delta_1+\Delta_2+\Delta_3+\Delta_1'+\Delta_2'+\Delta_3'=6\Delta.$$

Equating two values of Δ', we have

$$\frac{\delta_1}{p_1}+\frac{\delta_2}{p_2}+\frac{\delta_3}{p_3}=\frac{-\delta+\delta_1+\delta_2+\delta_3}{2r}$$

Let $\delta_1=p_1,\ \delta_2=p_2,\ \delta_3=p_3,$ . . . . (C)

and this becomes

$$\frac{p_1}{r_1}+\frac{p_2}{r_2}+\frac{p_3}{r_3}-\frac{p_1+p_2+p_3}{r}+6=0.$$

Again, let

$\delta_1=a,\ \ \delta_2=b,\ \ \delta_3=c$ . . . . (D)

and the same formula gives

$$\frac{a}{p_1}+\frac{b}{p_2}+\frac{c}{p_3}+\tfrac{1}{2}\left(\frac{a}{r_1}+\frac{b}{r_2}+\frac{c}{r_3}\right)=\frac{s}{r}.$$

An Inquiry into the Fundamental Principles of Algebra, chiefly with regard to Negative and Imaginary Quantities. By C. F. Ekman.

On Definite Integrals. By Bierens de Haan.

On Geometrical Rests in Space. By Sir W. R. Hamilton, *M.R.I.A.*

On the Roots of Substitutions. By the Rev. T. P. Kirkman, *M.A., F.R.S., Honorary Member of the Literary and Philosophical Societies of Manchester and Liverpool.*

The group given at page 6 of the "Transactions of the Sections of the British Association for 1860" is one of the equivalents of a grouped group, which is of the class described by M. Camille Jordan in the 4th chapter of his Thèse "Sur le Nombre des Valeurs des Fonctions" (Paris, Mallet-Bachelier, 1860, or Journal de l'Ecole Polytechnique, 1861). The first four substitutions of that group form one of the grouped groups described by Cauchy in his "Mémoire sur les Arrangements," &c. (Exercices d'Analyse et de Physique Mathématique, tome troisième).

M. Jordan's group is formed by writing in the auxiliary group

1234
2143
3412
4321,

for 1, $\frac{12}{21}$; for 2, $\frac{34}{43}$; for 3, $\frac{56}{65}$; for 4, $\frac{78}{87}$.

This gives a grouped group G, from which is obtained the equivalent

G′=34127856 G 34127856,

in page 6 quoted above.

The two groups of Mr. Cayley at page 5 of the same Report, are grouped groups whose general theory has not, so far as I know, been given. In fact the auxiliary groups on which they are constructed are of a kind entirely new, of which a brief account may be seen at the end of my memoir "On the Theory of Groups and many-valued Functions," in the forthcoming volume of the 'Memoirs of the Literary and Philosophical Society of Manchester,' 1861.

These auxiliaries are,

$$(h)\quad \begin{array}{l} 1234 \\ 2^2143^2 \\ 3^24^212 \\ 43^221^2, \end{array} \qquad \begin{array}{l} 1234 \\ 2^214^23 \\ 3^2412^2 \\ 4^23^221. \end{array} \quad (h')$$

The peculiarity of these groups (h, h') is that the four elements therein are affected with different exponents, which are essential to the groups, and cannot disappear from them or from their equivalents.

Thus (h) and (h') give the two groups

12345678	12345678
21436587	21436587
43127865	43128756
34218756	34217865
65871234	65781243
56782143	56872134
78653421	87653412
87564312	78564321

which are equivalent to the two groups at page 5 above quoted.

Thus we have, by a direct tactical process, found the 12 *regular square roots of the substitution* 21436587.

What has just been done is a case of a more general theorem.

If we define that

$$1^{2a-1}=1,\quad 2^{2a-1}=2,\quad 3^{2a-1}=3,\quad 4^{2a-1}=4,$$

and that the addition of the same number to *all the exponents* of the elements of a substitution makes no change in the substitution, we find that the two following are true groups, by the usual test, that the product of any two substitutions of the group is a substitution of the group

$$\begin{array}{ll} H. & H'. \\ 1234 & 1234 \\ 2^a143_a & 2^a14^a3 \\ 3^a4^a12 & 3^a412^a \\ 43^a21^a & 4^a3^a21 \end{array}$$

e. g. $3^a\,4^a12\,.\,2^a143^a=4^{2a-1}\,3^a\,21^a=43^a\,21^a,$

$3^a\,4^a\,12\,.\,43^a\,21^a=21^a\,4^a\,3^{2a-1}=21^a\,4^a\,3=2^a\,143^a.$

We may substitute in either H or H′ for each one v of the four elements a group u of $2a-2$ powers made with $2a-2$ elements, and for v^a the result of $a-1$ cyclical permutations of the vertical rows of u. The constructed is always a grouped group, which is no group of powers, nor equivalent to that built on the auxiliary with $a=1$, if we take a such that it shall not be prime to $2a-2$, that is, if we take for a any even value.

When a is odd, H and H′ are still groups, and proper auxiliaries; but I believe that the grouped group constructed will always be equivalent to the one formed by taking $a=1$, that is, the two groups will differ neither in the number nor in the orders of the circular factors of their substitutions.

There is but one square root of unity in the group given by H when $a=4$, of *which the group contains twelve 6th roots of the 12th order, with all their powers.*

It is perfectly easy to write out by a direct tactical method the eighteen cube roots, and the eighteen 6th roots of the substitution $\phi=231564897$, all of the 9th order, considered in page 6 of last year's Report.

For this purpose we employ the groups

123	123	123	123	123	123
$2^{2}31$	$2^{3}31$	$23^{2}1$		231^{2}	231^{3}
$3^{2}12$,	$3^{3}12^{3}$,	$3^{2}1^{2}2$,	$3^{3}1^{3}2$,	$31^{2}2^{2}$,	$31^{3}2^{3}$,

which are all easily proved to be groups. For example, in the second,

$$2^{3}31 \,.\, 3^{3}12^{3} = 1^{3}2^{3}3^{3} = 123.$$

$$3^{2}12^{3} \,.\, 2^{3}31 = 1^{3}2^{3}3^{3} = 123.$$

We readily formed the grouped groups,

123456789	123456789	123456789
231564897	231564897	231564897
312645978	312645978	312645978
564789123	645789123	456897123
645897231	456897231	564978231
456978312	564978312	645789312
897123456	978123645	897231456
978231564	789231456	978312564
789312645	897312564	789123645, &c.

There are six groups, each containing three cube roots of 231564897 and three cube roots of 312645978, that is three 6th roots of 231564897.

All these are mere groups of nine powers, and are therefore no addition to our knowledge of groups; but they are formed by the process of *evolution*, as *grouped groups of roots*, comprising of necessity *all powers of those roots*, whereas such groups are usually formed by the process of *involution*.

Every group of powers of a substitution which has two or more circular factors of the same order can be written out either by the process of *involution*, beginning with a *principal* substitution next to unity, or by the process of *evolution*, beginning next to unity with a substitution of a *lower* or of the *lowest order*, by means of an auxiliary group.

For example, the eight cube roots of 214365 are written by the auxiliary groups

123	123	123	123
231	$2^{2}31$	$23^{2}1$	231^{2}
312	$3^{2}12^{2}$	$3^{2}1^{2}2$	$31^{2}2^{2}$,

which are all that we can employ, as $1^{3}=1$, $2^{3}=2$, $3^{3}=3$, when the elementary groups represented by 1, 2, and 3 are of the 2nd order.

When the circular factors of the auxiliary group are of an order prime to that of those of the elementary group represented by 1 2 3 . . in the auxiliary, all the auxiliaries formed by different systems of exponents give grouped groups equivalent to that given when all the exponents are unities in the auxiliary. We have just had proof of this, in the three groups last constructed. But when the circular factors of the auxiliary are not prime to those of the elementary groups, we obtain by certain systems of exponents grouped groups not equivalent to that given by the auxiliary whose exponents are all unity.

If, for example, we mean $\frac{12}{21}$ by 1 and $\frac{34}{43}$ by 2, the two auxiliaries $\frac{12}{21}, \frac{12}{2^{2}1}$ give the groups

1234	1234
2143	2143
3412	4312
4321	3421,

which are not equivalents.

The Influence of the Rotation of the Earth on the Apparent Path of a Heavy Particle. By the Professor Price, *M.A., F.R.S., Oxford.*

The problem of the apparent path of a heavy particle as affected by the diurnal rotation of the earth, of course comes within the grasp of the general equations of *relative* motion. As these last will be found in treatises on mechanics, where such subjects are considered, it is unnecessary to do more than insert the forms of them which express the circumstances of our problem, and explain the symbols employed. A particle is supposed to be projected with a given velocity (which in the case of a falling particle may be zero) in a given direction. The place on the earth's surface, whence the particle is projected, is taken as the origin; the axes of x and of y are taken in the horizontal plane, and are respectively north and south, and east and west, the positive direction of x being taken towards the south, and that of y towards the west; and the z-axis is the vertical line measured upwards from the earth towards the zenith of the place; and this line may be assumed without sensible error to pass through the earth's centre. The latitude of the place is λ; and ω is the angular velocity of the earth; g is the force of gravity of the earth, and is considered to be constant for all points of the path of the particle (m). Then the equations of motion are

$$\left.\begin{aligned}&\frac{d^2x}{dt^2}-x\,\omega^2(\sin\lambda)^2-z\,\omega^2\sin\lambda\cos\lambda+2\,\omega\sin\lambda\frac{dy}{dt}=0,\\&\frac{d^2y}{dt^2}-y\,\omega^2-2\,\omega\left(\sin\lambda\frac{dx}{dt}+\cos\lambda\frac{dz}{dt}\right)=0\\&\frac{d^2z}{dt^2}-x\,\omega^2\sin\lambda\cos\lambda-z\,\omega^2(\cos\lambda)^2+2\,\omega\cos\lambda\frac{dy}{dt}=-g.\end{aligned}\right\}$$

Now ω is a very small quantity; to determine its value I will take a second to be the unit of time: then, as a mean sidereal day contains 86164·09 seconds,

$$\omega=\frac{2\pi}{86164{\cdot}09}=\frac{1}{13713}=\cdot00007292.$$

Consequently ω^2, which enters into the preceding equations, is an extremely small fraction. Also in the present problem, notwithstanding the increase of range now obtained by the improved weapons of projection, x, y, z are all very small parts of the earth's radius; and therefore in the first approximate solution of the preceding equations, I will neglect those terms which contain products of these coordinates and of ω^2; so that the equations become

$$\left.\begin{aligned}&\frac{d^2x}{dt^2}+2\,\omega\sin\lambda\;\frac{dy}{dt}=0,\\&\frac{d^2y}{d^2t}-2\,\omega\left(\sin\lambda\frac{dx}{dt}+\cos\lambda\frac{dz}{dt}\right)=0,\\&\frac{d^2z}{dt^2}+2\,\omega\cos\lambda\;\frac{dy}{dt}=-g.\end{aligned}\right\}$$

As these are linear equations of the first order, they are easily integrated; and if u=the velocity of projection, and α, β, γ are the direction-angles of the line of projection, we have

$$x=u\,t\cos\alpha-u\,\omega\sin\lambda\cos\beta\,t^2,$$
$$y=u\,t\cos\beta+u\,\omega(\cos\alpha\sin\lambda+\cos\gamma\cos\lambda)\,t^2-\omega\,g\cos\lambda\,\frac{t^3}{3},$$
$$z=u\,t\cos\gamma-\left(\frac{g}{2}+u\,\omega\cos\lambda\cos\beta\right)t^2;$$

which three equations give the place of the projectile at the time t. Now, without proceeding further at present in the process of approximation, let us consider two particular cases and results, which are of considerable interest.

(1) Let the body fall, as *e. g.* down a mine, without any initial velocity; then $u=0$; $\cos\alpha=\cos\beta=0$; $\cos\gamma=-1$;

$$\left.\begin{aligned}\therefore\ x&=0,\\y&=-\omega\,g\cos\lambda\,\frac{t^3}{3},\\z&=-\frac{1}{2}g\,t^2.\end{aligned}\right\}$$

The first equation shows that there is no deviation in the line of the meridian: from the second we infer a deviation towards the east; that is, in the direction towards which the earth is moving; which varies as the cube of the time of falling; and that this deviation is greatest at the equator, where $\lambda=0$: and the last equation shows that the earth's rotation does not produce any alteration in the time of falling.

If we eliminate t, and take z downwards to be positive,

$$y^2=\frac{8\,\omega^2(\cos\lambda)^2}{9\,g}z^3;$$

which is the equation to a semicubical parabola, and shows that the square of the deviation towards the east varies as the cube of the space through which the particle has fallen.

(2) Let the particle be projected due southwards at an angle of elevation equal to θ; then

$$\cos\alpha=\cos\theta,\ \cos\beta=0,\ \cos\gamma=\sin\theta;$$

and

$$\left.\begin{aligned} x&=u\,t\cos\theta,\\ y&=u\,\omega\sin(\theta+\lambda)\,t^2-\omega\,g\cos\lambda\,\frac{t^3}{3},\\ z&=u\,t\sin\theta-\frac{gt^2}{2}.\end{aligned}\right\}$$

From the first and the last of these equations we infer that neither the time nor the range on the meridian is altered by the rotation of the earth. Also when $z=0$, that is, when the projectile strikes the ground, $t=\frac{2\,u\sin\theta}{g}$; in which case

$$y=\frac{4\,u^3\,\omega\,(\sin\theta)^2}{3\,g^2}\{\sin\theta\cos\lambda+3\cos\theta\sin\lambda\};$$

and therefore the point where the projectile strikes the ground is west of the meridian so long as θ is less than $180°-\tan^{-1}(3\tan\lambda)$: and the deviation vanishes if $\theta=180°-3\tan^{-1}(3\tan\lambda)$. The deviation is eastwards if θ is greater than $180°-3\tan^{-1}(3\tan\lambda)$.

Now these results, which have herein been applied to the motion of a material particle, are also true of that of the centre of gravity of a body. Neglecting therefore the resistance of the air, and the action due to the rotation of a ball or bolt, they are applicable to rifle and cannon practice, and we have the following results.

When the shot is fired due north or south, the range in that direction is not altered, but there is always a deviation of the shot, the value of which at the point of impact on the ground is given in the last equation.

Also from the preceding equations the following results may be deduced:—

When the shot is fired due east, the range eastwards is increased or diminished according as the angle of elevation of the gun is less than or greater than 60°; and the deviation is southwards for all places in the northern hemisphere, and northwards for all places in the southern hemisphere.

When the shot is fired due west, the range is increased or diminished according as the angle of elevation is greater than or less than 60°; and the deviation is northwards for all places in the northern hemisphere, and southwards for all places in the southern hemisphere.

So that for firing from a place in a direction coincident with the parallel of latitude, and with an elevation less than 60°, the range is increased or diminished according as we fire eastwards or westwards; and the difference between the two ranges

$$=\frac{8\,u^3\,\omega\cos\lambda}{3\,g}\{3(\cos\theta)^2-(\sin\theta)^2\};$$

and if the place is in the northern hemisphere, the deviation parallel to the meridian is north or south, according as we fire west or east.

Now these effects have been inferred from the equations of motion, simplified by the assumption that products of ω^2, and one of the relative coordinates of m, are small quantities, and are to be neglected. Let us now retain these quantities, and assume that products of ω^3 and of a small variable are to be neglected; and that all small quantities of a lower order are to be retained.

We shall suppose the values of x, y, z given above to be approximate solutions of the first order of the equations; and if, according to the general method of solution adopted in such cases, we substitute these values in terms involving $\omega^2 x$, $\omega^2 y$, and $\omega^2 z$, that is in the smallest terms which we intend to retain, and, omitting terms of higher orders, then integrate the simultaneous differential equations thus formed, the results are

$$x = ut\cos\alpha - u\omega\sin\lambda\cos\beta\, t^2 - u\omega^2\sin\lambda(\cos\alpha\sin\lambda + \cos\gamma\cos\lambda)\frac{t^3}{2} + g\omega^2\sin\lambda\cos\lambda\frac{t^4}{8};$$

$$y = ut\cos\beta + u\omega(\cos\alpha\sin\lambda + \cos\gamma\cos\lambda)\, t^2 - \omega g\cos\lambda\frac{t^3}{3} - u\omega^2\cos\beta\frac{t^3}{2};$$

$$z = ut\cos\gamma - \frac{1}{2}gt^2 - u\omega\cos\lambda\cos\beta\, t^2 - u\omega^2\cos\lambda(\cos\alpha\sin\lambda + \cos\gamma\cos\lambda)\frac{t^3}{2} + g\omega^2(\cos\lambda)^2\frac{t^4}{8}.$$

These equations, of course, give results corresponding to particular initial circumstances. I will take only two.

(1) Let the body fall without any initial velocity; then $u=0$, $\cos\alpha = \cos\beta = 0$, $\cos\gamma = -1$;

$$\left.\begin{aligned} x &= \omega^2 g\sin\lambda\cos\lambda\frac{t^4}{8}, \\ y &= -\omega g\cos\lambda\frac{t^3}{3}, \\ z &= -\frac{1}{2}gt^2 + \omega^2 g(\cos\lambda)^2\frac{t^4}{8}. \end{aligned}\right\}$$

The first equation shows that there is a deviation of the falling particle in the line of the meridian towards the south; and the second shows that the deviation in the parallel of latitude is towards the east; so that the resulting deviation of the falling body is towards the south-east. This result is in accordance with the case many years ago investigated by Hooke, the contemporary of Sir I. Newton. From the last equation it appears that the space due to a given time is less than it would be if there were no rotation.

(2) Let the body be projected due southwards at an angle of elevation equal to θ, so that $\cos\alpha = \cos\theta$; $\cos\beta = 0$; $\cos\gamma = \sin\theta$; then

$$\left.\begin{aligned} x &= ut\cos\theta - u\omega^2\sin\lambda\sin(\lambda+\theta)\frac{t^3}{2} + g\omega^2\sin\lambda\cos\lambda\frac{t^4}{8}, \\ y &= u\omega\sin(\lambda+\theta)\, t^2 - \omega g\cos\lambda\frac{t^3}{3}, \\ z &= ut\sin\theta - \frac{gt^2}{2} - u\omega^2\cos\lambda\sin(\lambda+\theta)\frac{t^3}{2} + g\omega^2(\cos\lambda)^2\frac{t^4}{8}. \end{aligned}\right\}$$

When the projectile strikes the ground, $z=0$; and approximately $t = \frac{2u\sin\theta}{g}$; in which case

$$y = \frac{4u^3\omega(\sin\theta)^2}{3g^2}\{\sin\theta\cos\lambda + 3\cos\theta\sin\lambda\};$$

which is the same expression as that just now interpreted. Consequently the aim of a long-range gun pointed due north or south must be in accordance with the preceding explanations.

On the Calculus of Functions, with Remarks on the Theory of Electricity.
By W. H. L. RUSSELL, *A.B.*

The object of this paper was to give some account of a method discovered by the author for the solution of functional equations with rational quantities, known functions of the independent variable, as the arguments of the unknown functions. The solutions were given by series, and also in terms of definite integrals.

On Petzval's *Asymptotic Method of solving Differential Equations.* *By* William Spottiswoode, *M.A., F.R.S.*

The researches of M. Petzval here brought under notice are directed to the solution of those linear differential equations with variable coefficients which have reference to motions, themselves small, but propagated to great distances. In such equations y usually represents the disturbance, and x the distance from the origin. If then the solution $y=f(x)$ be considered as the equation to a curve, the method proposed by the author will give the values of y corresponding to large values of x; in other words, the asymptotes to the curve in question. Hence the name "Asymptotic Solution."

With a view to this object M. Petzval proposes the following question: Can any general laws be established, with respect to the coefficients of a differential equation, capable of furnishing criteria for determining the nature of the particular integrals which satisfy it? Having first made such a classification of functions as renders his conclusions capable of conversion, in the logical sense of the term, he proceeds to form, from a given equation of the degree n,

$$X_n y^{(n)}+X_{n-1} y^{(n-1)}+ \ldots X_0 y=(X,y)^{(n)}=0,$$

the equation of the degree $(n+r)$, $(Z,z)^{(n+r)}=0$, arising from the introduction of r particular integrals of a given form.

Passing over the case of algebraic integrals, some of the criteria of which are common to exponentials, the more important cases are as follow:—

I. Particular integrals of the form $\epsilon^{\alpha x}Q$, where Q is an entire algebraic polynomial.

(1) To a *level* (*i. e.* an equality of degrees among consecutive coefficients) in $(X,y)^{(n)}=0$, there corresponds in general a level among those of

$$(Z,z)^{(n+1)}=0.$$

(2) To a level among $X_{k+r-1}, X_{k+r-2}, \ldots X_k$, followed by a continuous fall among $X_{k-1}, X_{k-2}, \ldots X_0$, of $(X,y)^{(n)}=0$, there corresponds a level among $Z_{k+r}, Z_{k+r-1}, \ldots Z_k$, followed by a similar fall among $Z_{k-1}, Z_{k-2}, \ldots Z_0$, of $(Z,z)^{(n+1)}=0$.

II. Of the form $\epsilon^{\alpha x^2+\psi(x)}Q$, or $\epsilon^{\beta x}Q$, where $\psi(x)$ is defined to belong to the author's first class.

(1) To a continuous rise among $X_n, X^{n-1}, \ldots X_{n-r+1}$, of $(X,y)^{(n)}=0$, there corresponds in general a similar rise among $Z_n, Z_{n-1}, \ldots Z_{n-r}$, of $(Z,z)^{(n+1)}=0$.

(2) To a continuous fall among $X_{k-1}, X_{k-2}, \ldots X_0$, of $(X,y)^{(n)}=0$, there corresponds in general a similar fall among $Z_{k-1}, Z_{k-2}, \ldots Z_0$, of $(Z,z)^{(n+1)}=0$.

III. Of the form $\epsilon^{\int\phi(x)dx}Q$, where the degree of $\int\phi(x)dx$ is fractional, $=\frac{p}{q}$, and consequently that of $\phi(x)$ is $\frac{p-q}{q}=-\frac{\delta}{q}$.

(1) If $\frac{p}{q}$ be a proper positive fraction, to a level among $X_{k-1}, X_{k-2}, \ldots X_0$, of $(X,y)^{(n)}=0$, there corresponds a fall among $Z_{r-1}, Z_{r-2}, \ldots Z_0$, of $(Z,z)^{(n+r)}=0$, amounting in all to $\frac{r\delta}{q}$.

(2) If $\frac{p}{q}$ be an improper positive fraction, to a level among $X_n, X_{n-1}, \ldots X_{n-r+1}$, of $(X,y)^{(n)}=0$, there corresponds a rise among $Z_{n+r}, Z_{n+r-1}, \ldots Z_{n+1}$, of $(Z,z)^{(n+r)}=0$.

IV. Of the forms $\epsilon^{\psi(x)}\frac{Q}{(x-a)^k}$, and $\epsilon^{\int\frac{\phi(x)}{(x-\alpha)^m}dx}$,

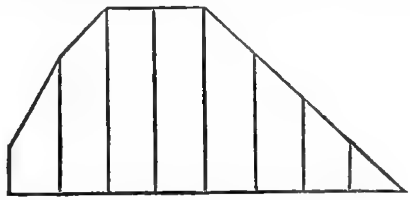
to a series of coefficients $X_n, X_{n-1}, \ldots X_{n-r+1}$, of $(X,y)^{(n)}=0$, free from the factor $(x-a)$, there corresponds a series $(x-a)^{a+b+\ldots}Z_{n+r}$, $(x-a)^{b+\ldots}Z_{n+r-1}, \ldots (x-a)^k Z_{n+1}$, of $(Z,z)^{n+r}=0$.

The general result to which the author brings these conclusions, together with the exceptional cases, not here specified, will be best exhibited by the following examples.

Example 1. Let the degrees of the coefficients be

$$1, 3, 4, 4, 4, 3, 2, 1, 0,$$

the equation being of course of the 8th degree. Then construct the following figure, in which the ordinates are proportional to the degrees of the coefficients:



The differences between the degrees of the coefficients are

$$2, 1, 0, 0, -1, -1, -1, -1;$$

and consequently the degrees of $\psi(x)$ in the particular integrals of the equation will be

$$3, 2, 1, 1, 0, 0, 0, 0;$$

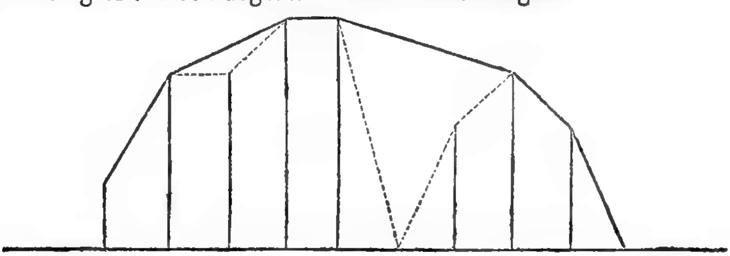
so that in the general solution there will be

One integral of the form $\epsilon^{\alpha x^3+\beta x^2+\gamma x}Q$,
One " " $\epsilon^{\alpha x^2+\beta x}Q$,
Two " " $\epsilon^{\alpha x}Q$,
Four " of a purely algebraic form.

Example 2. Let the degrees of the coefficients be

$$1, 3, 3, 4, 4, 0, 2, 3, 2, 0,$$

the equation being of the 9th degree. Then form the figure



where, after bridging over the re-entering angles, the differences of the degrees are

$$2, \frac{1}{2}, \frac{1}{2}, 0, -\frac{1}{3}, -\frac{1}{3}, -\frac{1}{3}, -1, -2;$$

and consequently the degrees of the exponentials $\psi(x)$ will be

$$3, \frac{3}{2}, \frac{3}{2}, 1, \frac{2}{3}, \frac{2}{3}, \frac{2}{3}, 0, -1.$$

About the degree -1 there is a difficulty; but the author suggests that the negative index arises from an accidental cancelling of the highest power of x in Z_0, and that it may probably be replaced by zero.

On the Reduction of the decadic Binary Quantic to its Canonical Form. By William Spottiswoode, *M.A., F.R.S.*

Professor Sylvester has shown that the quantic

$$(a_0, a_1, \ldots a_{2n} \between x, y)^{2n}$$

may be reduced to the form

$$u_1^{2n} + u_2^{2n} + \text{—} u_n^{2n} + \Lambda V u_1 u_2 \ldots u_n,$$

in which Λ is a constant, and V a covariant of the product $u_1, u_2, \ldots u_n$, satisfying a certain differential equation. In applying his method to the 10th degree, the greatest simplification of which the calculations are susceptible is effected by supposing that the product $u_1, u_2, .. u_5$ has been reduced to its canonical form, viz. $x^5+y^5+(\lambda x+\mu y)^5$. Then the differential equation which V must satisfy takes the form

$$\left\{\frac{\partial^5}{dy^5}-\frac{\partial^5}{dx^5}+\left(\lambda\frac{\partial}{dy}-\mu\frac{\partial}{dx}\right)^5\right\}\mathrm{V}\left\{x^5+y^5+(\lambda x+\mu y)^5\right\}=\theta\left\{x+y^5+(\lambda x+\mu y)^5\right\};$$

where θ is a constant.

Developing the differential equation and equating the coefficients of the powers and products of x, y in the two sides, we have a series of linear equations for determining the ratios of $\alpha:\beta:\gamma\ldots$; from the solution of which it turns out that *each of the coefficients of the covariant* V *is equal to the product of* $\lambda^p\mu^q$, *multiplied by a rational integral function of* λ^5, μ^5, *independent of all intermediate powers of* λ, μ.

On the Involution of Axes of Rotation.
By Professor Sylvester, *M.A., F.R.S.*

After a brief statement as to the most general mode of representing the displacement of a rigid body in space by means of angular rotations about six distinct axes fixed in position, it was shown that under peculiar conditions the six axes would become insufficient, being, in fact, equivalent to a smaller number, in which case they would be said to form a system in involution. Various constructions for representing such and similar systems were stated, and the remarkable conclusion presented, that the necessary and sufficient condition for three, four, five, or six lines being thus mutually, as it were, implicated and involved consists in their lying in ruled surfaces of the first, second, third, and fourth orders respectively. The theory of involution originated with Prof. Mobius, by whom, however, it had been left in an imperfect condition. The author referred for further information on the subject to some recent notes by himself in the 'Comptes Rendus' of the Academy of Sciences of Paris, and to certain masterly geometrical investigations of M. Chasles and Mr. Cayley, to which these had given rise.

Astronomy.

On the Almanac. *By* M. N. Adler.

In this paper the author gave easy methods for finding, by a direct mental process, the fundamental points requisite in forming the almanac for any year.

Remarks on Dr. Hincks's *Paper on the Acceleration of the Moon's Mean Motion as indicated by the Records of Ancient Eclipses.* *By the* Astronomer Royal.

The author stated his unaltered conviction that the Tables of Hansen gave the date of the great solar eclipse which terminated the Lydian war, as all the most reliable records of antiquity fixed it, in the year 585 B.C. He said he must first recall to their remembrance some geographical facts, and he sketched on the board a rough plan of Asia Minor, Upper Asia, the Black Sea, and the Mediterranean. An impassable mountain barrier, which the ancients called Mount Taurus, stretches across between Asia Minor and Upper Asia, leaving only two passes at all practicable for an army: one to the north, along the shore of the Black Sea, celebrated for the well-known retreat of the Ten Thousand Greeks, as chronicled by Xenophon, but so extremely difficult that only one army besides had ever traversed it; the other to the south-east of Asia Minor, through which, all the circumstances rendered it highly probable, the invading Assyrian army entered Asia Minor, as it was certain the army of Alexander the Great passed through it in the opposite direction when he invaded Syria, Egypt, and Upper Asia; and every other recorded march between Asia Minor and Upper Asia had been made through the same pass. Now, in the line between this pass and the capital of Lydia it was nearly certain the decisive battle was fought, and calculation from the Tables showed that at the date assigned to the eclipse, commonly called the Eclipse of Thales, because predicted by him, the centre of a total eclipse of the sun actually swept over this district. The Astronomer Royal then explained how Thales was able, by the aid of the Saros, or period of 18 years 15 days and 8 hours, to predict the eclipse; and then, if the previously-observed eclipse at the beginning of this cycle occurred in the morning (which agrees with calculation), the odd 8 hours would ensure that this one would occur in the afternoon (which also agrees with calculation), and the eclipse might really be predicted, as was recorded. He then pointed out how calculation from the same Tables led us to the time and circumstances of the eclipse of Agathocles, when the Grecian fleet escaped out of the harbour of Syracuse; also to the darkness, which, no doubt, was an eclipse, which was stated to have taken place when the Persian army entered Larissa or Nimrud.

On the Resistance of the Ether to the Comets and Planets, and on the Rotation of the latter. By J. S. Stuart Glennie, *M.A.*

This paper was an application to the motions of the comets and planets of the following theorem, on the hypothesis, favoured or adopted by Encke and Pontécoulant, of a medium whose resistance is inversely as the square of the distance from the sun. According as the resultant of the resistance to a revolving and rotating body passes or not through the centre of gravity, will it affect the revolution or the rotation of the body.

Some Considerations on M. Haidinger's *Communication on the Origin and Fall of Aërolites. By* R. P. Greg, *F.G.S.*

M. Haidinger and Dr. Laurence Smith differ in their opinion as to the cause and origin of the blackish-coloured crust observed in almost all meteoric stones; the latter conceives that they were thus coated previous to their entering the confines of the earth's atmosphere; the former much more reasonably alleges that it has been caused by simple superficial fusion after the meteorite has entered the atmosphere, either by resistance to the air causing heat, or by the superheated air surrounding the stony matter of the fireball itself. Dr. Smith seems to have been misled by circumstances presented on the fall of some very large stones in Ohio, May 1, 1860, which evidently at the time of their fall could not have been very hot. But he seems to have overlooked the fact stated by Haidinger, that in *large* stones (especially) the internal parts must affect the temperature of interplanetary space, and tend almost instantaneously to efface the very superficial heat caused by the sudden fusing of their exterior.

M. Haidinger and Dr. Smith both agree in thinking that meteorites enter our atmosphere more commonly in groups or "flocks" of small fragments, than as a single and larger mass. This seems to me opposed both to fact and probability. In the case of the celebrated fall of meteoric stones at L'Aigle in Normandy, in 1803, April 26, though it is quite true that nearly 3000 stones fell (the major number not larger than walnuts, and the largest only seventeen pounds), yet we must bear in mind that but one single fireball was seen previously to the bursting and fall of the meteorite. The stones presented irregular shapes, chiefly angular, with the edges slightly rounded, and all similarly covered with a crust. Surely it is more natural to conceive that one large fragment was by explosion and unequal heating broken up into many smaller ones. Moreover, were individual fireballs to contain within themselves numerous small stones, would it not rather militate against M. Haidinger's theory, since the opposing air would then pass between them like a sieve, and the whole *notion of the head of the meteorite* forcing up before it the film of air that is to curl up behind (to contain the vacuum which on the collapse of the fireball is to cause the noise), *would have to be abandoned as untenable.*

M. Haidinger's idea that the noise or report is caused by the collapse of the vacuum carried forward in the rear of the fireball deserves attentive consideration, and much might be said in favour of it as well as against it. Besides the possibility of the noise being due to the discharge of electricity, Dr. Smith likewise considers the noise is not caused by the bursting of a solid, but rather by concussion in the atmosphere arising from the rapid motion of the body through it*. Mr. Benjamin

* But, then, why should we not hear the noise produced by the simple passage of any

Marsh, in his able notice of the great daylight meteor in the United States, November 15, 1859, affirms, however, that the *sound* following the bursting of that meteor "was explosive, and *not* caused by the falling in of the air after the meteor, as in the latter case it must have been continuous and interrupted; but the testimony of Dr. Beesley and others shows that it ceased entirely and then began again. Suppose the meteor to have been a stony mass, we may perhaps consider the explosion to have consisted of a series of decrepitations caused by the sudden expansion and heating of the surface. At the forward end these explosions would take place under great pressure, which may account for the loudness of the sound." Again, "the explosions were very numerous, the whole occupying only half a second of time; but the individual sounds were distinguishable because of the different distances they had to travel to reach the ear; the whole duration of the sound extending in reality over a minute."

Though I am inclined to agree to a great extent with Mr. Marsh respecting the cause and effects of the sound being caused by a series of decrepitations taking place, under pressure of the resisting atmosphere, yet that would hardly explain the sudden disruption and disappearance of fireballs, actually occurring in the majority of cases; it would be too gradual a breaking up to accord altogether with facts.

One obstacle in the way of a satisfactory solution arises from the difficulty of ascertaining the real size of an aërolitic fireball, which at the distance of 40 miles or more may appear as large as the moon; for it has been proved that a very small body, such as a small stone, when in a state of powerful incandescence, appears much larger than it really is; *e. g.*, Dr. Smith has himself shown that a piece of lime less than half an inch in diameter, in the flame of the oxyhydrogen blowpipe, has, in a clear evening, appeared at the distance of half a mile to present an apparent diameter equal to twice that of the moon! On the other hand, while this fact seems to afford us facilities for a simple solution, it may still be quite possible that the stony matter is but a nucleus inside a larger envelope of highly compressed and heated air, containing likewise, as Haidinger supposes and explains, the vacuum, which subsequently collapses with a loud report.

It may be here mentioned, that occasionally large meteors (evidently aërolitic) have been seen to divide into two nearly equal portions (a loud detonation following some minutes afterwards), and that both have then passed off again into space without other apparent change*.

It is also equally certain that no noise is heard unless a large fireball actually bursts into two or more considerable portions; and that the principal noise is certainly the direct result of this rupture. How such violent noises and atmospheric concussions as take place are produced and also heard and felt on the surface of the earth is strange, and as yet not fully understood: the height at which fireballs thus burst varies from 15 to 40 miles. The cases where stones have fallen from fireballs without noise are very rare indeed.

Dr. Laurence Smith considers the *light* emitted by fireballs does not arise from mere incandescence, but is caused by electricity and other causes. M. Haidinger speaks of air heated to whiteness. There must, however, be a certain amount of light arising from the incandescence of solid matter, judging from the fused crusts of all aërolites, and from the fact of some meteorites, especially *iron* ones, being known to fall red-hot; but that at heights of from 20 to 40 or even 100 miles, where the supply of oxygen must be inconceivably small, part of the light may be owing to a development of electricity, seems highly probable.

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large meteor? No noise is ever heard unless the entire fireball is ruptured or flies to pieces. Besides, at elevations of 30 or 40 miles the air would be too rarefied to produce much noise from simply rushing into the space left in the wake of the meteorite.

* As was the case with the celebrated meteors of August 18, 1783, in England, and that of July 20, 1860, in North America; which being the fact, goes against M. Haidinger's theory of incandescent air enclosing a vacuum in the rear of the main fireball; for the bursting would, in the cases just cited, probably have destroyed, at least temporarily, their subsequent visible existence. In these two cases it seems most reasonable to suppose that a large stone (several feet in diameter), while in a state of high superficial incandescence, "broke" into two parts with a loud crack or report, the sound of which, under the very great pressure caused by resistance to the atmosphere, would be greatly magnified or increased.

In briefly alluding to the origin of meteorites, I consider it now almost universally admitted by the highest authorities, that, mineralogically speaking, aërolites falling to the earth are merely fragments of larger rocks, some of which may be considered to be strictly volcanic: whether stone or iron, they enter our atmosphere as irregular-shaped fragments, which may again become broken into smaller fragments before reaching the surface of the earth. In explaining the original or "nascent" state of meteoric matter as he does, M. Haidinger is simply proposing a new theory to account for the original condition of planetary matter and its consolidation; and whether that was fluid or gaseous, or *pulverulent*, may perhaps be a step too remote for the present state of aërolitic investigation; though whether their present condition will throw additional light on the physical history of our own earth, or the reverse, I am not prepared at present to say. The idea that meteoric stones are fragments of a larger and broken-up mass of planetary matter, itself originally formed, as I understand it, by the external consolidation, by gravitation, of fine impalpable dust, in the form of an external crust (or series of concentric crusts), internally contracting somewhat after the manner of septaria, and afterwards, from heat, chemical action, unequal expansion, bursting like a projectile filled with explosive material, is certainly a bold idea, and I only regret that M. Haidinger's abstract of his original paper does not more fully give all his facts, comparisons, and arguments. To my own mind, however, the idea of an original state of fine planetary *dust* is not satisfactory; for *dust* rather implies the notion of waste, or wear and tear of matter already previously consolidated.

However originally formed, our meteoric planet may in the course of time be supposed from some cause or other to become broken up into fragments more or less dispersed, and occasionally, in the form of aërolites, to come into contact with our own earth. This may be all the more probable, when I add that I hear that M. Leverrier has quite recently come to the conclusion that there exists "a mass of matter equal to about $\frac{1}{10}$th of the mass of the earth revolving round the sun at very nearly the same mean distance as the earth, and which is probably split up into an immense number of small asteroids." (See Monthly Register of Facts for August 1861.)

The structure, composition, and specific gravity* of *meteorites* agree very closely with that of similar rocks on our own globe; and it may not be unreasonable to suppose that the former are representatives of that mysterious planetary matter, of whose aggregate mass M. Leverrier has just informed us, and which in the course of ages, at the rate of several thousand tons annually, may eventually be all absorbed, as Reichenbach has suggested, by our own earth.

An attempt to account for the Physical Condition and the Fall of Meteorites upon our Planet. By W. Haidinger, *Hon. Mem. R.S. L. & E., H.F.R.G.S., F.F.G.S., H.M. SS. of Cambridge, Manchester, Edinburgh, Truro, &c.*

I beg leave to lay before the British Association for the Promotion of Science, the outline of some considerations which have been impressed on my mind during late studies in this most interesting department of physical science, and one which is still involved in many difficulties and contradictions.

In order to give a more general view of the present state of progress, I mention the names of some of the more active promoters of the science in our own days. The Imperial Collection at Vienna, which took the lead under v. Schreibers and Partsch, is still foremost under Dr. Hörnes, but closely followed by Prof. Shepard in New Haven; Baron Reichenbach in Vienna; the British Museum under the enlightened superintendence of Mr. Nevil Story Maskelyne; Prof. Gustavus Rose in Berlin; Prof. Wöhler in Göttingen; Mr. R. P. Greg in Manchester,—each possessing from 100 to 163 meteorites with distinct dates of fall or discovery; to the labours of the above-named, add also those of Rammelsberg, Laurence Smith in Louisville, Kentucky, O. Buchner in Giessen. The recent remarkable falls of aërolites near New Concord, and in Guernsey County, Ohio, on the 1st of May, and near Dharamsala, Kangra, Punjab, on the 14th of July, both in 1860, the

* The iron masses that occasionally fall are supposed by M. Haidinger very reasonably to have originally existed as *veins* in the original meteoric planet.

large iron masses brought to light near Melbourne in Australia, and other facts full of interest, are keeping alive the attention of philosophers.

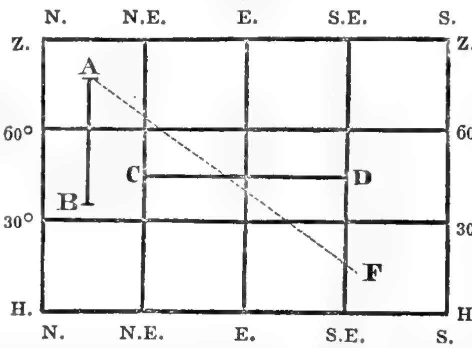
Having joined my excellent friend Dr. Hörnes in the wish to enlarge our Imperial Collection of aërolites, I have from time to time had to give notice of several newly observed facts, and at each step to endeavour to account for some one or other peculiarity. As a result, it seemed to me that I had arrived at a pretty complete theory both of the circumstances attending the fall of meteorites, and the conditions of their consolidation before they entered our atmosphere.

Explanations relative to the telluric fall of aërolites, though more known than formerly, are still not devoid of many difficulties; but these are far surpassed by the difficulties attending the cosmic question, which in fact amount to nothing less than a complete theory of the original formation of celestial bodies generally, at least of the two which come into contact with each other, the aërolite and our own planet. I beg leave to begin with some considerations on the first of these questions.

1. *The Phenomena of the Fall of Aërolites.*—There can be no doubt relative to the fact that the crust of aërolites, and their body or mass, are formed in two different ways, the one by superficial melting, the other by long-continued consolidation. The form of aërolites betrays them originally to have been *fragments.* This is most universally granted. In this direction Sir David Brewster and Humboldt gave their verdicts; this also has been placed forward by Laurence Smith and Mr. Greg. "Viewed from most positions, the largest meteoric stone (that of 103 lbs. weight, in Marietta College, Ohio, from the fall of May 1st, 1860) is angular, and appears to have been recently broken from a larger body." Many other examples might be adduced.

It is well known that in some cases, as at Strakowitz, on November 28th, 1859, and Pegu, December 27th, 1827, the semblance of enlarging and approaching aërolitic fireballs has been observed and described. In these cases the altitude and geographic orientation should be carefully inscribed in a diagram like fig. 1, in order to be able, by comparison with the exact time of hour, day, and year, to find the region from whence they travelled to meet our earth. A B (fig. 1) would be the track of a meteor arriving from an altitude of 75° in the N.N.E., and exploding or extinguished at an altitude of about 40°, while C D might denote a meteor that seemed to travel horizontally from 45° N.E. to 45° S.E., its true course being from N. to S., but visible from the side. Observations from several distinct places, when combined together, will allow the real track to be ascertained with considerable accuracy. This was finely exemplified in the Ohio fall of May 1, and in the grand meteor of July 20th, 1860, of Elmira, Long Island, and other places in the United States.

Fig. 1.



Viewed from a distance, there is an impression on the eye of a fireball, sometimes more or less lengthened, or ending in a sharp pointed tail, and moving with amazing velocity. When viewed very near, aërolites have been seen to fall down like any other stone, and with no greater velocity.

The velocity of meteors varies from 20 to upwards of 140 miles (4 to $23\frac{3}{4}$ German miles), according to joint observations of Julius Schmidt at Bonn (now at Athens), Heis at Aix la Chapelle, and Houzeau at Mons, as recorded in Humboldt's 'Cosmos.' This wonderful velocity may be compared with that of phenomena familiar to us upon our own planet. Commander M. F. Maury, U.S., quotes from Sir John Herschel's article "Meteorology" in the 'Encyclopædia Britannica,' 1857, the velocity of 92 English miles in an hour for a "Devastating Hurricane," or only 134·9 feet in one second of time, with a horizontal pressure of 37·9 lbs. to a square foot. The following data are given in Rouse's Anemometric Tables in the Report of the Tenth Meeting of the British Association, &c., at Southampton, in September 1846. (London, 1847, p. 344):—

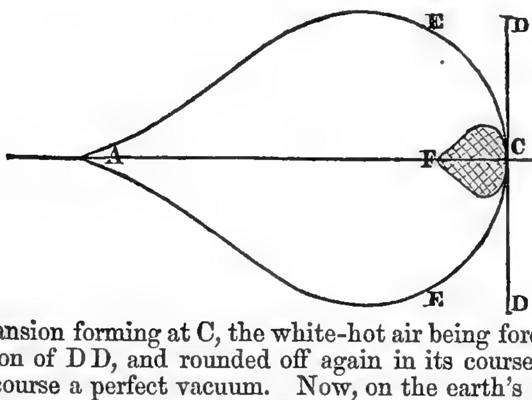
Velocity of the wind.		Pressure on the square foot in lbs. avoirdupois.	Character of wind.
English miles in one hour.	English feet in one second.		
60	88·02	17·715	Great storm.
80	117·36	31·490	Hurricane.
100	146·70	49·200	Destructive hurricane.
913 to 916	1340·00	One atmosphere.	

But the pressure of the atmosphere is equal to 32 feet of water, of the weight of 49·71 lbs. avoirdupois; for 1 cubic foot is equal to 1590·7 lbs., or 42 times the pressure on one square foot of a destructive hurricane. From other data I inferred the pressure 55 times the pressure of a devastating hurricane. Evidently these numbers are all approximations. It may be observed here, that it is this pressure of the atmosphere which enables it to remain in its undisturbed state, while the rate of movement of a point in the equator, by rotation, is no less than 1340 feet in one second of time.

When a fragment of rock enters the atmosphere with the great velocity above mentioned, the particles of air, though remote from each other at the height where the fragment moves, and at the low temperature of cosmic space (some 100° Centigr. below the freezing-point of water), will be carried along forcibly, without the possibility of giving way or flowing off laterally, the rapidity of motion being too excessive. The air will unavoidably be compressed, and both heat, electricity, and light must be developed. A centre of expansion must be generated exactly in front of and close to the moving fragment, and the compressed air, heated to whiteness, will be forced out on all sides perpendicularly to the direction of the track of the meteor. But as the latter still advances, the pressure of the opposing atmosphere upon the white-hot shining disc will round it off, so as to produce the oval fireball as it appears to our eye.

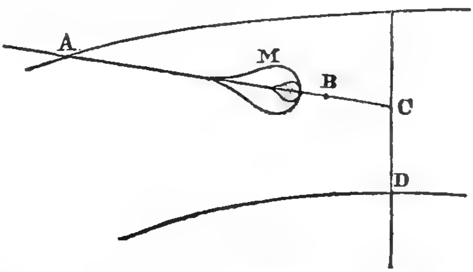
I beg leave to refer to the diagram, fig. 2—the meteor moving from A to B, the

Fig. 2.



centre of expansion forming at C, the white-hot air being forced out perpendicularly in the direction of D D, and rounded off again in its course at E E, to meet at A, enclosing of course a perfect vacuum. Now, on the earth's surface one square foot of "destructive hurricane" will produce a pressure of 37·9 lbs., while it travels at the rate of 134·9 feet in one second of time. One square foot of a meteor supposed to travel at the rate of 35 miles, or of 35 times 5280 feet, in the same second of time (a distance 1370 times greater than the former), may be considered to exert a pressure of 51,923 lbs., or of more than thirty-two atmospheres. These amazing, though of course only approximate, numbers will certainly give sufficient cause for an increase in the temperature and development of light. This construction, I believe, will not be considered inconsistent with observations, or contradictory to well-known physical facts. It accounts in particular for the fact that from fireballs of very considerable magnitude, stony or iron specimens are obtained of very diminutive size and weight. The heat evolved by compression is sufficient to melt the surface. From some peculiarities visible on the surface of aërolites—the well-known pits, roughness or smoothness, rounded and bulging-out edges—it may be inferred that some of the single stones connected with a fall of a swarm or shower, or the greater number of them, have not been detached from a larger body, but that they have entered the atmosphere unconnected with any other, and have always kept one position, the fore part and sides being uniformly rough, while the back part, though smoother, is covered with depressions, showing what has been called the "pitted" surface of meteorites.

Fig. 3.



The compression of the air of the atmosphere, and the centre of expansion formed, will not only give the rise in temperature, produce light, and form a ball, but it must also impart a rotatory movement, and at last arrest the solid matter (stone or iron) in its course. The *cosmic* portion of its track, still continuing at A, fig. 3, when the meteorite M enters the atmosphere, is closed at C, and from thence it drops simply to the ground at D, in its *telluric* track, like any other heavy body, gravitating only towards our planet. Particles scaling off at a point B may appear like sparks to us, while the surface may easily be covered again by a new but thinner crust, before the stone reaches the point C. Stones falling to the earth in this way appear black in the air, from the comparative slowness of movement, several of them together sometimes resembling "a flock of birds." No fireball is seen where the aërolitic bodies themselves can be distinguished, as is stated, among other falls, in that of New Concord, Ohio, of May 1, 1860.

During the time of the downfall and immediately after it, the temperature of the crust, which must have been sufficiently high to melt it, again meets the low temperature of the interior of the aërolite, which must have been the same in the larger aërolite as that of cosmic space. It is said that large masses when taken up appear to the touch "no warmer than if they had lain on the ground exposed to the sun's rays." This is the expression used by Prof. Laurence Smith, when speaking of the fall of New Concord and of Guernsey County on the 1st of May, 1860. The mass of iron which fell, January 1844, in the Caritas Paso, in Corrientes (R. P. Greg, Philosophical Magazine for July 1855), came down, however, most intensely heated, which prevented a near approach to it, even some hours after its fall. But this may also be accounted for by the greater conducting power of iron for heat. On the other hand, fragments of stone taken up, *e. g.*, after the fall of Dhurmsala or Dharmsala, Kangra, Punjab, on July 14, 1860, were found so intensely cold, that the natives who took up some of them, "before they had held them in their hands half a minute, it is said, had to drop them, owing to the intensity of cold, which quite benumbed their fingers." No description relative to the matter of which these Dharmsala stones consist has as yet been published.

One very peculiar feature attending in most instances the fall of meteorites, is the phenomenon of "terrific bursting noise," of "reports most terrible, filling the neighbourhood with awe," frequently "several of them following each other;" as also that characteristic "rumbling" which follows the main reports, or a sequel of peals of musketry, and sometimes hissing sounds. I should venture to propose a solution dependent simply on the well-known physical fact, that sound more or less loud may be produced from the mere suddenly filling up of an empty space or vacuum with air. I am happy to say that I am supported in this supposition by Prof. Laurence Smith, who likewise, quite independently, came to the same result. These reports, or succession of several reports, are called "explosions," and, generally speaking, the fireballs at the same time disappear. But certainly it is not such an explosion as we might expect from a projectile filled with gunpowder. On the contrary, when the meteor considered above is arrested by the atmosphere, then the air rushing in from all sides would fill up the vacuum, till then surrounded by the film of incandescent air emanating from the centre of expansion in front of the advancing fireballs.

I believe I am safe in assuming the following deductions as well explained:—

1. The incandescent ball is produced by the compression of the atmospheric air.

2. The sounds, reports, and rumblings are produced by the concussion of the air in the vacuum of the fireball when arrested.

3. Showers of aërolites in the generality of cases are produced by groups of meteorites entering our atmosphere together. There may be in some cases larger masses flying to pieces by rotation.

4. The crust is produced by the melting of the superficial portion of the fragments. The high temperature produced is lowered immediately after the beginning of the real fall by the intense cold of the interior.

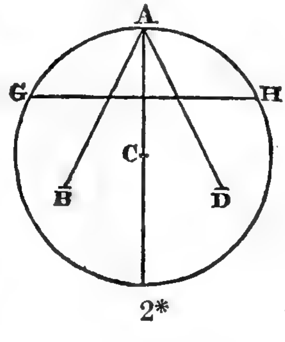
I have enumerated these points to show the concordance in some, and the difference of opinion in others, of those enumerated by Prof. Laurence Smith in Silliman's American Journal, vol. xxxi. January 1861, p. 98.

II. *Origin of the rocky substance of Aërolites.*—Having to account for a *fragment* of rock broken off from its original repository and traversing cosmic space by itself, the question is simply to give, as a first step, an outline of the possible consolidation of matter in its most attenuated condition into a solid body, and then to give a plausible cause why it may be shattered to pieces. The theories of the present day, that of La Place at the head of them, are familiar to philosophers. All of them must assume cosmic matter in the finest state of *dust* to begin with. But the assumption of a temperature so high as to contain only one thirteen-millionth part of a grain (0·000013) in a cube of space, the side of which is of the length of one German mile, is far too gratuitous, as well as inconsistent with our knowledge of the physical properties of matter. We know cosmic space to be intensely cold. For thousands of years there has been no change experienced relative to the temperature of the earth's surface.

It may be a question whether it may not be possible for heat to be generated even in the cold of cosmic space, by the simple action of gravitation upon the particles of attenuated matter, in their most *nascent state.* This will lead to consequences closely agreeing with the views of De la Rive, Sir Charles Lyell and others, as to the production of the central heat of our planet, as quoted by Prof. Naumann in his treatise on Geology, page 63. Now we may arrange all sorts of meteoric rocks in an uninterrupted series, beginning with the most crystalline state that many meteorites and meteoric irons frequently exhibit, and following them up to several of those *marbled* composite specimens, such as those of Parnallee, Bremevörde and others, which bear the closest resemblance to our tufaceous deposits, but in which no water has been at work. I have ventured to propose for this characteristic structure the expression of "Meteoritic Tufa." And even beyond that, there are still more tender and fragile specimens, approaching to mere aggregations of powder or dust, like the one of the fall at Alais, March 15, 1806, or of Cold Bokkeveld of October 13, 1838. It is certainly a fair induction to suppose the more solid and crystalline of these rocks to have been formed out of the consolidation of matter originally in a state of dust, or nascent.

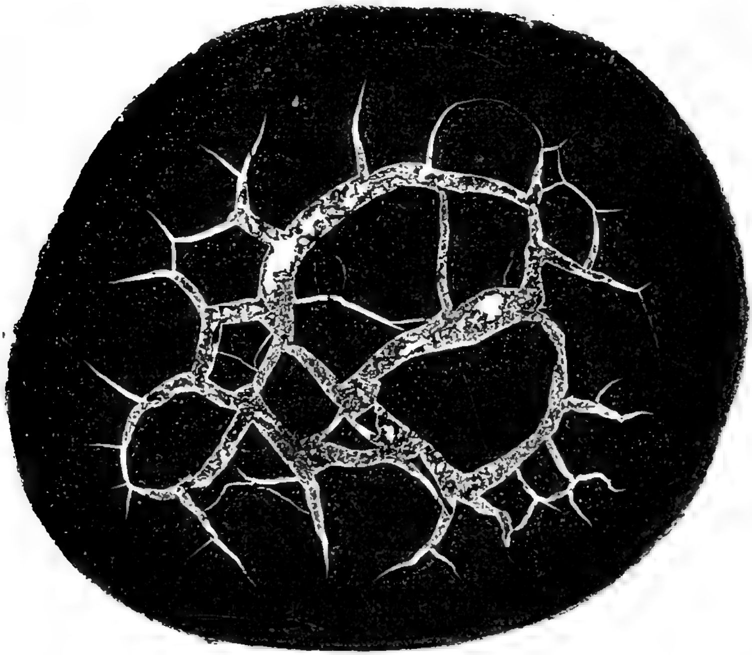
If we conceive the diagram, fig. 4 (taken from Dr. Kopp's article, "Physik und Meteorologie," in the Bädeker publication on Natural Science, Die gesammten Naturwissenschaften), to represent a large globe of cosmic matter in the state of the finest impalpable dust in its most "nascent state," every point situated like A will be attracted with equal force by other points B and D similarly situated, so that its total direction will tend towards the centre C. Near the centre, the attraction towards it will not be nearly so powerful; in the centre itself gravitation will have no definite direction at all, the particles of matter being solicited by attraction in each of the diverging directions. Consolidation then will depend upon the pressure coming into play from the surface stratum only.

Fig. 4.



As a very nearly analogous case, I may turn to the well-known "Septaria" concretions, consisting chiefly of carbonate of iron or clay iron ore, compressed from without and yielding to pressure, till the outward stratum has assumed so much of consistency that it will act like an arch or vault against further pressure, while the inside still remains in a softer state, which, however, is afterwards lost by contraction of the main substance, while in the fissures carbonates of lime and magnesia, or even iron pyrites, are deposited. The diagram (fig. 5) is taken by stereotype from a specimen in the Imperial Mineralogical Museum of Vienna.

Fig. 5.



In the very same manner a solid crust or shell may be the result of pressure from without, on the stratum most distant from the centre, in a large globe of cosmic matter. Pressure will elicit electric action, chemical action will ensue, and heat and light be disengaged, sufficient to form all those combinations and compound rocks, as they come now within our reach in aërolites, or meteoric stones and irons; some of them in the shape of massive rocks of tufaceous structure, others becoming granular in composition, some traversed by veins, others (and particularly irons) having the character of being the products of veins containing fragments or imbedded crystals, as of olivine or chromite.

Pressure on the surface depends upon the magnitude of the globe itself: while a portion of matter weighing one pound upon our earth will press upon the surface of it with the effect appertaining to one pound, it will only press with the effect of $\frac{2}{13}$ths of one pound upon the surface of the moon, but with that of $28\frac{1}{2}$ pounds upon that of the sun. The same pressure which is produced in our planet by a crust of 25 miles, upon the moon will only be produced by a crust of $162\frac{1}{2}$ miles; upon the sun by a crust of only $\frac{15}{17}$ths of a mile, or of only 4656 feet. Heat is then the result of pressure. I may be permitted to quote here a passage from the 'Abstracts of the Proceedings of the Geological Society of London,' No. 24, January 5, 1859, in which Prof. Ramsay, communicating a paper by Mr. T. Sterry Hunt, states, "The author accepts the views of Babbage and Herschel as to the internal heat of the earth rising through the stratified deposits, on account of the superficial accumulation of sediments, metamorphosing the rocks submitted to its action, causing earthquakes and volcanic irruptions by the evolution of gases and vapours from chemical reactions, and giving rise to disturbances of equilibrium over wide areas of elevation and subsidence." We then have great authorities for the increase of heat by means of increase of thickness of deposits. The same must certainly be allowed also at the very first, and when cosmic matter is in its most attenuated dust-like state.

Pressure will take place only so long as there is no consolidation of matter. Solid matter presses upon its support, but is steady within itself. The gradual evolution of heat is confided to the hearth of pressure. What we observe of rising temperature as we descend is *conducted* heat from that hearth, where it is *generated*, and from which streams of lava are forced up and volcanic action is developed.

Suppose now a complete solid shell of a very large globe to have been formed, and to be perfectly balanced, and sufficiently steady to withstand any further approach towards the centre. But this shell is still filled with the original cosmic matter, which itself may go on by a similar process to form a new shell concentric to the former one, and developing heat again exactly as in the first instance. A new hearth of volcanic action is thus produced, while the original one becomes extinct. Then the possibility arises, that within this confined space, heat and the expansion of gases might be brought to so high a degree of tension as to break the shell with an actual explosion, as with hollow projectiles filled with gunpowder, launching fragments of every size in all possible directions, to travel on for time unmeasurable through cosmic space.

What is the reason of the great discrepancy in the density of the celestial bodies of our solar system? Does this depend only on the elementary substances of which they consist, in a manner analogous to our own earth; or is that difference founded, partially at least, in the progress of their formation? We have the densities of Mercury=6·71, of the Earth=5·44, of Mars=5·15, of Venus=5·02, of the Moon =3·37, of the Sun=1·37, of Jupiter=1·29, of Neptune=1·21, of Uranus=0·98, of Saturn=0·75.

It is well known that Olbers first conceived the possibility of Ceres and Pallas being fragments of a former larger body. When the asteroids Juno and Vesta had been discovered, Lagrange* gave the numeric conditions of an exploding force under which it might be possible that an exploding planet would yield fragments to become comets, or, more properly speaking, to move in orbits of comets, direct or retrograde, elliptic, parabolic, or when more violent into hyperbolic orbits, to leave our solar system altogether after the first perihelion. Now he found that at the distance of a hundred times the distance of the earth from the sun, an exploding force would suffice, giving an impulse only from twelve to fifteen times greater than the velocity of a cannon-ball—about 1400 feet in one second, which is about the same as the velocity of a point in the equator in the diurnal revolution of our earth.†

Although some of the considerations may appear too bold and extravagant, yet I think I have nowhere supposed anything to take place which would not enter within the compass of well-known physical occurrences upon our own earth. I believed it my duty to collect together in a short sketch the considerations which had occurred to me, while I have for some time past had an opportunity of examining some facts, and of reporting on others, concerning meteorites.

I beg leave to lay them before the public, wishing they might induce the friends of scientific progress to take a still more lively interest both in observing facts and in collecting materials (by publishing the former and preserving the latter in the leading Museums) relative to these curious celestial bodies, in order to advance our ideas in these as yet comparatively obscure branches of science.

Finally, I may be permitted to recapitulate the entire series of steps in the progress of the formation of meteorites.

I. *Original Formation.*

1. The creation of matter—atoms of elements as they are familiar to us, in their *nascent state.*

* Sur l'Origine des Comètes.—Connaissance des Tems pour l'an 1814, p. 211.

† If it were assumed as a plausible hypothesis that heavenly bodies in the manner above alluded to might fly into pieces, having their fragments transformed into planets, asteroids, or aërolites, then one step further might bring in connexion with the same explosions also the origin of comets. The solid crust of the shell would supply more solid bodies, while the aërial portion and the finest dust-like residue, being isolated in cosmic space, but still acted upon by gravitation (in so far as it would not disperse altogether, having also received an impetus or launch in one direction), would assume the shape and nature of a comet!

2. Large globes are formed by rotation, consisting of cold cosmic dust, similar in shape, but not in matter, to those supposed by La Place's theory, which are red-hot liquids.

3. Consolidation begins from the outermost stratum near the surface. Pressure within elicits electric and chemical action: heat is disengaged: new compounds are formed, gaseous, liquid and solid.

4. A hollow shell of solid matter is generated, containing within it matter still in progress of consolidation, as exhibited to some extent by septaria.

5. The difference of tension within and without the shell causes a real explosion, by which fragments are dispersed in cosmic or interplanetary space to traverse it in all directions.

II. *The arrival of Meteorites upon our Earth.*

1. A fragment in its course comes into contact with our globe.

2. The fragment is arrested by the resistance of the atmospheric air. It may in many cases pounce directly upon the earth.

3. Pressure on its passage through the atmosphere elicits light and heat, rotation ensues, and a melted crust is formed.

4. The white-hot compressed air is spread out in the form of a fireball, closed up behind, the fragment enclosing a vacuum space.

5. The cosmic course is at an end when the fragment has been arrested by the air.

6. Light and heat are no longer generated: the ball will collapse with a loud report, or several following each other.

7. The cosmic cold within the aërolite assists in reducing the heat of the melted crust.

8. The meteorite falls down upon the earth like any other ponderous body, the hotter the better conducting material it consists of.

On the Quantity of the Acceleration of the Moon's Mean Motion, as indicated by the Records of certain Ancient Eclipses. By the Rev. Edward Hincks, *D.D.*

The question which the author proposed to discuss was whether the acceleration of the moon's mean motion relatively to the sun and stars was 12 or 13 seconds, multiplied by the square of the number of centuries from 1800, or only about two-thirds of that magnitude. The quantity assumed by M. Hansen in his lunar tables is 12″·18; and the Astronomer Royal has given his opinion that this is somewhat too small. The question is not to be decided by theory. Professor Adams has shown that the quantity which would be produced by gravity is far less than this, and less than is certainly indicated by observation; and that, consequently, some other cause than gravity must have been in operation. Theory cannot determine what is due to this unknown cause; and therefore the quantity of the acceleration can be determined by observation alone.

The observations on which the Astronomer Royal relied were solar eclipses, of which he believed that there were four, of which there were such authentic records as to determine with tolerable accuracy the quantity of the acceleration. He rejected the records of lunar eclipses, on account of the want of precision which there must be in the observations. In the present paper the author endeavoured to show that the four alleged eclipses of the sun, on which the Astronomer Royal relied, furnished no sufficient data for determining the acceleration; and that, on the other hand, there were at least two of the lunar eclipses recorded by Ptolemy which afforded means of determining the quantity of the acceleration with tolerable accuracy, and which, if the author's calculations were correct, proved that it did not much exceed 9″.

The four eclipses of the sun on which the Astronomer Royal relied were that of Agathocles (−309, Aug. 14), as to the date of which there is no question, nor as to its totality where the fleet was; the latitude in which the fleet was, is however, within certain limits, an indeterminate quantity, as is the hour when the eclipse began. While therefore this eclipse affords conclusive evidence of the fact that the moon's motion formerly was less than it is now, it proves nothing as to the question now discussed, whether the acceleration was about 9″ or between 12″ and 13″. It is admitted that the former supposition would satisfy the requirements o the record; and it is admitted that even 12″ would be too great for these requirements, unless the motion of the node were altered also. This eclipse ought, therefore, the author maintained, to be put out of the account. Whatever weight it had was, he said, on his side of the balance. It was the same with the eclipse of Thales (−584, May 28). Of this there were two records, real or supposed. There is one preserved by Theon, which certainly applied to it; and this is consistent with, if it do not render necessary, the supposition that the acceleration is overrated by Hansen. The other is the statement of Herodotus, that the eclipse which terminated the Lydian war was that which was predicted by Thales; in which case the eclipse must have been total in the eastern part of Asia Minor; and this it could not be if the acceleration were only 9″. The author objected to this second record, and charged the Astronomer Royal with arguing in a vicious circle in respect to it. He inferred that the acceleration was so great as he makes it, because this is necessary to make the eclipse satisfy the statements of Herodotus; while in defiance of authentic chronology he makes the Lydian war to have terminated in 585 B.C., because the lunar tables, assuming the acceleration to be thus great, give a track of the shadow which would satisfy the condition of the eclipse which terminated the war. Dr. Hincks, on the contrary, maintained that if the acceleration were only about 9″, either the eclipse of 610 B.C. or that of 603 B.C. might be made to satisfy the requirements of the eclipse which terminated the Lydian war; the motion of the node being suitably altered to a very moderate extent. The record of Theon respecting the eclipse of 585 B.C. is that Thales predicted that an eclipse of the sun would take place, and that accordingly there was an eclipse *at the Hellespont*. The author inferred from this that the eclipse was not visible in Greece, or at Miletus or Sardis; but that the shadow entered the north-western parts of Asia Minor a little before sunset, and left the earth before it reached the middle of the peninsula. This would be in accordance with his views as to the quantity of the acceleration. The third of the Astronomer Royal's eclipses is the so-called eclipse of Larissa (−556, May 19). He assumes that a cloud which was said to have obscured the sun when this city was taken by the Persians, was in fact the moon eclipsing him. The date of the transaction is not mentioned, nor the name of the king of Persia who took the city. The Astronomer Royal has put together a number of arbitrary hypotheses, all of which are required to be true in order that his conclusion should stand. The only *fact* to which he appeals is that if Hansen's tables were perfectly correct, the centre of the moon's shadow, which was very narrow, would in that eclipse pass over Larissa. If, however, the tables were perfectly correct, as he admits himself, the eclipse of Agathocles would not have been total in any possible position of his fleet. He is therefore obliged to suppose that the tables required to be corrected both as to the acceleration, which must be increased 0″·8, and as to the motion of the node; and that in the eclipse of Larissa these two corrections exactly neutralized one another! The author of the paper considered this to be almost infinitely improbable, the breadth of the shadow being so small as it was. The remaining eclipse of the Astronomer Royal was the so-called eclipse of Stiklastad. On the 31st of August, 1030, being *Monday*, there was a total eclipse of the sun in Norway; and Professor Hansteen pretends that this eclipse caused the darkness which is said to have been observed when the saint-king Olaf was killed in the battle of Stiklastad. But the chronicler expressly states that this battle took place on *Wednesday*, the 29th of July, thirty-three days before the eclipse. The week-day is particularly noticed, as well as the month-date; and moreover it appears from the same chronicle that the eclipse in the Orkney Islands, which took place on the 5th of August, 1263, was *after* the day observed as St. Olaf's day, which was the day of the battle in which he was killed. From this it is quite manifest that this eclipse is a figment of the Danish Professor, and that no weight whatever should be allowed to any evidence that it is supposed to furnish.

Having disposed of these four solar eclipses, not one of which, as the author contended, offers any reliable evidence that the moon's acceleration exceeded 9″, he proceeded to consider some lunar eclipses, observed at Babylon, the records of which were preserved by Ptolemy. The Astronomer Royal had not taken these into account; but the author maintained that the true quantity of the acceleration could be computed from them with much greater accuracy than from the records of the solar eclipses. He relied on the two eclipses of the year −719. In that of March 8, it is recorded that the middle of the eclipse took place at Babylonian midnight. As we know from the astronomical tablets found by Mr. Layard that the Babylonians measured the time from apparent noon by clepsydras, which ran out in two hours, the time of midnight, being at the end of the sixth *kazb*, or running out of the clepsydra, would be known with great precision, so that an error of above a few minutes in the time of the middle of the eclipse is inadmissible. An error of twelve minutes can scarcely be supposed possible. This, however, would represent an error of about 325″ in the mean elongation, or about 0″·57 in the coefficient of the acceleration; while no error which we can suppose possible in the motion of the node would sensibly affect the result. It appears from this, that the record of this eclipse enables us to determine the quantity of the acceleration with far more accuracy than do any of the records of solar eclipses. Dr. Hincks has calculated the circumstances of this eclipse from Hansen's tables; and without laying much stress on his calculations, which required to be verified, he would state that the middle of the eclipse took place about 11 P.M. Babylonian time, and that the moon must have been completely out of the shadow before midnight. The other eclipse was on the 1st of September; and it is recorded that it began *after the moon had risen*. This statement is one about which a mistake would be impossible. And yet, according to the author's calculation from Hansen's tables, the moon was more than two digits eclipsed when she rose at Babylon. But this is not all. He argued that Ptolemy's reasoning respecting this eclipse implied that his records stated that the eclipse did not commence till some time, probably half an hour, after the moon had risen. The sun, he says, set at seven; *consequently* the eclipse began at half-past seven, Babylonian time. If then the author's calculation be correct, there is an error of more than an hour in the time when this eclipse commenced, which of course must be occasioned by Hansen's having overrated the acceleration. The author concluded by saying that he did not expect or wish that his calculations should be held conclusive; but he wished that others should make the calculations, and that these important data should not be ignored, as they had hitherto been.

Cases of Planetary Instability indicated by the appearance of Temporary Stars. By DANIEL VAUGHAN.

In a paper which I sent to the British Association four years ago, I ascribed the perpetuity of the sun's light to the combustion of ether collected from space by his attraction, and compressed at his surface to a density sufficiently great for the play of chemical forces. I showed that the brilliancy of luminous meteors is the necessary consequence of the great pressure which rapidly moving bodies impart to the envelope of this luciferous fluid belonging to the earth, and that the dormant photospheres which it forms for dark central bodies, when traversed by worlds in the last stage of existence, must give birth to a vast illumination, exhibiting to us the peculiar characters of the temporary stars. The main results of my subsequent researches on the subject have been published in the 'London, Edinburgh, and Dublin Philosophical Magazine;' and in two communications which appeared in the Numbers for December 1860, and April 1861, the more obvious cases of the instability of satellites from the reduced size of their orbits have been investigated, partly with a view of tracing the course of great meteoric displays in the heavens. In these I have supposed the central orb vastly superior to its attendant in mass and dimensions; but on examining the consequences which must ensue when the disproportion between both bodies is not so great, we render more satisfactory the explanation of temporary stars, without exceeding the limits of reasonable probability in estimating the number of dark systems in our universe.

In these investigations the hypothesis of solidity, in the sense usually received, should be abandoned. In very close proximity to a great central sphere, a satellite as large as the earth could not be considered unyielding, though composed of the strongest materials known; nor could it deviate much from the form which it might assume if reduced to a state of fluidity. In a very small orbit also, the disturbing forces operating on the yielding mass would have the ultimate effect of bringing the same point of its surface into perpetual conjunction with the primary planet.

In the absence of any arrangement for this purpose, the action of the primary on the protuberant solid or liquid matter which swells by its enormous tidal force on the satellite, must constantly accelerate or retard the rotation of the latter, until it is caused to keep exact trace with the orbital movement. Whilst the synchronism confines the great tide-wave to a limited range, the tendency of the shortest diameter to become the axis of rotation will gradually bring the equator into a coincidence with the plane of the orbit; and both causes would have the ultimate effect of giving the body a permanent elongation at the same localities. If the eccentricity of the orbit were then sufficiently great to occasion high tides on its seas or oscillation in its solid matter, the resulting deviation from a sphere will not reach its highest limit until some time after the central disturbance became most energetic, while a corresponding interval must elapse between the periods when the ellipticity and the disturbing power sink to the lowest degree. It will readily appear that such changes in the form of the satellite must cause it to feel a greater amount of attractive force while retiring from the primary than while approaching it; and a constant diminution of the eccentricity of the orbit is an inevitable consequence. Notwithstanding the small size of the four nearest moons of Saturn, it is not impossible that commotions on their surface may serve, in this way, to check the increase of eccentricity which might be expected to arise from the relation in their periods of revolution.

As a very large satellite, revolving within the range of a great central disturbance, must ultimately have its diurnal motion, the position of its axis, and the form of its orbit arranged in the peculiar manner necessary for keeping the same point of its surface always directed to the centre of the primary, the statical condition which the equilibrium of its parts assumes, presents a more easy subject for accurate scientific inquiry. In the April Number of the 'Philosophical Magazine,' I have shown that a homogeneous fluid satellite, whose size is very small compared with that of its orbit, would find repose in a form varying little from an ellipsoid, and that the intensity of gravity on its surface would be almost exactly proportional to the normal corresponding to each locality. It was also proved by the investigation, that the equilibrium is not possible when more than $\frac{3}{5}$ of the attraction along the major axis is neutralized by the centrifugal force and the disturbance emanating from the primary. In a former article, the radius of the smallest circular orbit in which the planetary form could be preserved was estimated as nearly equal to $2{\cdot}48\ R\sqrt[3]{\frac{D}{d}}$, R being the radius of the primary, D its density, and d the density of the satellite.

To cases of instability which may occur at any remote period in the systems of Jupiter and Saturn, these results would apply, with tolerable accuracy, even without corrections for the variable density of the bodies in their different parts. But were the central and the subordinate world in the same ratio as the earth and moon with respect to mass and volume, while their linear dimensions were ten times as great, the range of dangerous proximity would be a little wider than my estimate indicates, and the consequences near the confines of this dangerous domain would be much modified. The form of the lesser body would deviate considerably from a true ellipsoid; the disturbing forces must be very unequal at both extremities of the longest diameter; and the equilibrium cannot be equally secure at both localities. If, therefore, so large a satellite were introduced into the region of instability by the resistance of a space-pervading medium, the dismemberment would be confined to the side turned to the primary, and it would commence before weight entirely disappeared at any part of the surface. If it were composed of a fluid of uniform density, a reduction of even less than sixty per cent. in the attraction at the point nearest to the central orb would give rise to a movement towards this point, and cause it to assume such a character that it must be accelerated instead of being checked by the resulting change of form. A body of small size, in such circumstances, must soon have its whole contents scattered into space, from its two prominent extremities. In the present case, where the matter is pressed out only at the place next the primary, the enlargement which necessarily occurs in the orbit of the remaining mass lessens the disturbance, and brings the dismembering action to a close. The advantages for stability would also increase, as the large portion of the satellite launched into space retired far enough to make its attraction inappreciable. Accordingly a very large member of a dark system must close its mundane career, not by a single dilapidation of its planetary structure, but by a limited number of paroxysmal convulsions, each hurling forth an immense quantity of matter, with peculiarly favourable conditions for sweeping close to the central sphere, and forming a host of blazing meteors to encircle his surface.

Investigations on the effect of the departing mass in causing instability by its attraction, and of the opposite tendency of the expansion of the orbit, have led me to estimate the amount separated by each catastrophe at $\frac{V}{C}\sqrt{\frac{x^3}{A^3}}$, V denoting the volume of the satellite, A its longest semidiameter, and C a constant, which may be taken 8000 in case of a homogeneous fluid, but somewhat less when the body is solid. The influence of the opposing forces in limiting the range of the great rupture will diminish the loss which this expression would assign to a very large dismembering body. From the relative magnitudes of the earth and the moon, and the relation observed between the members of physically double stars, it would not be unreasonable to expect that central spheres 200,000 or 300,000 miles in diameter may have worlds capable of exhibiting, during their last stage of existence, a few hundred of these terrific scenes, and sending forth on many of them more meteorites than could be formed from our entire globe. Of the periods intervening between each, no precise estimate can be given, but it must doubtless comprise many centuries. On the first of these awful events, the meteoric light must be confined to the vicinity of the plane in which the attendant moved, and from which the fragments can deviate little; but these will soon form a ring around the primary, and make the luciferous action disappear. The mass launched forth on every subsequent paroxysm must move with terrific speed through the annular field of disconnected matter, scattering it in every direction, and causing it to extend the meteoric exhibitions over a much greater part of the surface of the central orb.

The pressure imparted to a fluid by a moving body is proportional to the cube of the velocity, though the resistance to motion, being equal to the difference of the pressure on two opposite sides, varies according to a different law. Now, if attraction causes the space-pervading ether to become more dense in the vicinity of the earth's surface, the excess of density must be increased almost a thousand-fold by the pressure of a meteorite passing through this ethereal atmosphere with the greatest velocity with which a body moving in an ellipse around the sun can approach the earth. Regarding meteors as luminous in consequence of this comparison, it is evident that they must display their light with the utmost splendour, and at the greatest elevations, on large spheres which exert the most powerful attraction on their surfaces. From the imperfect accounts which I have seen of Mr. Harrington's observations on September 1st, 1859, I have concluded that the meteors which he saw falling to the solar disc must have been self-luminous about one hundred thousand miles above the boundary of the great ocean of flame. When we consider the extraordinary brilliancy often attending the descent of these bodies to the earth, and reject the extravagant idea of gigantic meteorites supposed to escape into space after grazing or striking our atmosphere, we find additional proofs of the existence of dormant photospheres around obscure celestial orbs, and of the relation between objects so disproportionate in size as a shooting and a temporary star.

Physics.

On the Application of the Principle of the Conservation of Force to the mechanical explanation of the Correlation of Forces. By J. S. Stuart Glennie, *M.A.*

The author's chief object was to show that the principle of the conservation of force, with the facts of the correlation of forces, required a new or modified conception of matter. The principle of the conservation of force might be thus expressed: every motion is resisted, and produces a new motion, determined by the conditions of such resistance. To this principle the conception of matter, as made up of hard inelastic particles in an elastic ether, seemed to be opposed. Matter was rather to be conceived as made up of molecules, exerting mechanical pressure on each other through intervening molecules of the same kind, and the qualities of matter as depending on the motions of different orders of molecules. In pursuance of the same views, magnetic attractions and repulsions were to be referred to differential conditions of pressure.

Physical Considerations regarding the Possible Age of the Sun's Heat. *By* Professor W. Thomson, *F.R.S.*

The author prefaced his remarks by drawing attention to some principles previously established. It is a principle of irreversible action in nature, that, "although mechanical energy is indestructible, there is a universal tendency to its dissipation, which produces gradual augmentation and diffusion of heat, cessation of motion, and exhaustion of potential energy, through the material universe." The result of this would be a state of universal rest and death, if the universe were finite and left to obey existing laws. But as no limit is known to the extent of matter, science points rather to an endless progress through an endless space, of action involving the transformation of potential energy through palpable motion into heat, than to a single finite mechanism, running down like a clock and stopping for ever. It is also impossible to conceive either the beginning or the continuance of life without a creating and overruling power. The author's object was to lay before the Section an application of these general views to the discovery of probable limits to the periods of time, *past* and *future,* during which the sun can be reckoned on as a source of heat and light. The subject was divided under two heads: 1. On the secular cooling of the sun; 2. On the origin and total amount of the sun's heat.

In the first part it is shown that the sun is probably an incandescent liquid mass, radiating away heat without any appreciable compensation by the influx of meteoric matter. The rate at which heat is radiated from the sun has been measured by Herschel and Pouillet independently; and, according to their results, the author estimates that if the mean specific heat of the sun were the same as that of liquid water, his temperature would be lowered by 1°·4 Centigrade annually. In considering what the sun's specific heat may actually be, the author first remarks that there are excellent reasons for believing that his substance is very much like the earth's. For the last eight or nine years, Stokes's Principles of Solar and Stellar Chemistry have been taught in the public lectures on natural philosophy in the University of Glasgow; and it has been shown as a first result, that there *certainly is sodium in the sun's atmosphere.* The recent application of these principles in the splendid researches of Bunsen and Kirchhoff (who made an independent discovery of Stokes's theory) has demonstrated with equal certainty that there are iron and manganese, and several of our other known metals, in the sun. The specific heat of each of these substances is less than the specific heat of water, which indeed exceeds that of every other known terrestrial solid or liquid. It might therefore at first sight seem probable that the mean specific heat of the sun's whole substance is less, and very certain that it cannot be much greater, than that of water. But thermodynamic reasons, explained in the paper, lead to a very different conclusion, and make it probable that, on account of the enormous pressure which the sun's interior bears, his specific heat is more than ten times, although not more than 10,000 times, that of liquid water. Hence it is probable that the sun cools by as much as 14° C. in some time more than 100 years, but less than 100,000 years.

As to the sun's actual temperature at the present time, it is remarked that at his surface it cannot, as we have many reasons for believing, be incomparably higher than temperatures attainable artificially at the earth's surface. Among other reasons, it may be mentioned that he radiates heat from every square foot of his surface at only about 7000 horse-power. Coal burning at the rate of a little less than a pound per two seconds would generate the same amount; and it is estimated (Rankine, 'Prime Movers,' p. 285, edit. 1859) that in the furnaces of locomotive engines, coal burns at from 1 lb. in 30 seconds to 1 lb. in 90 seconds per square foot of grate-bars. Hence heat is radiated from the sun at a rate not more than from fifteen to forty-five times as high as that at which heat is generated on the grate-bars of a locomotive furnace, per equal areas.

The interior temperature of the sun is probably far higher than that at the surface, because conduction can play no sensible part in the transference of heat between the inner and outer portions of his mass, and there must be an approximate *convective* equilibrium of heat throughout the whole; that is to say, the temperatures at different distances from the centre must be approximately those which any portion of the substance, if carried from the centre to the surface, would acquire by expansion without loss or gain of heat.

Part II. *On the Origin and Total Amount of the Sun's Heat.*

The sun being, for reasons referred to above, assumed to be an incandescent liquid now losing heat, the question naturally occurs, how did this heat originate? It is certain that it cannot have existed in the sun through an infinity of past time, because as long as it has so existed it must have been suffering dissipation; and the finiteness of the sun precludes the supposition of an infinite primitive store of heat in his body. The sun must therefore either have been created an active source of heat at some time of not immeasurable antiquity by an overruling decree; or the heat which he has already radiated away, and that which he still possesses, must have been acquired by some natural process following permanently established laws. Without pronouncing the former supposition to be essentially incredible, the author assumes that it may be safely said to be in the highest degree improbable, if, as he believes to be the case, we can show the latter to be not contradictory to known physical laws.

The author then reviews the meteoric theory of solar heat, and shows that, in the form in which it was advocated by Helmholz*, it is adequate, and it is the only theory consistent with natural laws which is adequate, to account for the present condition of the sun, and for radiation continued at a very slowly decreasing rate during many millions of years past and future. *But neither this nor any other natural theory can account for solar radiation continuing at anything like the present rate for many hundred millions of years.* The paper concludes as follows:—"It seems therefore, on the whole, most probable that the sun has not illuminated the earth for 100,000,000 years, and almost certain that he has not done so for 500,000,000 years. As for the future, we may say with equal certainty that inhabitants of the earth cannot continue to enjoy the light and heat essential to their life for many million years longer, unless new sources, now unknown to us, are prepared in the great storehouse of Creation."

Light, Heat.

On Photographic Micrometers. *By* Sir David Brewster, *K.H., F.R.S.*

When examining, several years ago, some microscopic photographs executed by Mr. Dancer, the celebrated optician of this city, the author was struck with the singular sharpness and opacity of some of the lines in such of them as were copied from engravings. The idea occurred to him of obtaining photographically, by means of the camera, micrometrical scales, or systems of delicate lines, opake or transparent, and fitted both for astronomical and microscopical purposes. The suggestion was published in the article "Micrometer" in the 'Encyclopædia Britannica.' Mr. Dancer had succeeded in making photographic portraits on collodion so small that they were wholly invisible to the naked eye, and 10,000 portraits might be introduced into a square inch. The film of collodion upon which these photographs were taken was so thin and transparent that it was invisible, and allowed objects to be seen through it as distinctly as if it were the thinnest glass. If a system of opake or transparent lines, therefore, was impressed upon collodion or albumen photographically, when reduced to the minutest size from a system of large and sharply-defined lines, we should have the most perfect micrometrical scale that could be conceived. In the 'Philosophical Magazine' for August 1861, Dr. Woods, of Parsonstown, had suggested the construction of photographic micrometers without being aware of what had been published on the subject.

* Popular Lecture delivered at Königsberg on the occasion of the Kant Commemoration, February 1854.

On the Compensation of Impressions moving over the Retina. *By* Sir David Brewster, *K.H., F.R.S.*

The author stated that when, in railway travelling, they looked at the lines which the stones or gravel or other objects formed in consequence of the durations of their impressions on the retina, and quickly transferred the eye to the same lines further back, where the velocity was slower, the stones or gravel or other objects would, for an instant, be distinctly seen, just as rapidly revolving objects are seen in the dark when they are illuminated by an electric flash or the light of an exploded copper cap. A similar, but not the same, phenomenon will be seen when we look at the moving lines through a slit and quickly look away from the slit, so that the lines may be seen by indirect vision on a part of the retina not previously impressed. This class of phenomena may be best studied with a rapidly revolving disc, by quickly transferring the eye from the lines on the marginal part of the disc to those near the centre of rotation, where the velocity is less. When the marginal velocity is greatest, the point of compensation is nearest the centre, as might have been expected from the experiment in a railway carriage; but what could not, he thought, have been anticipated, was that the point of compensation was not in the same radius as the point to which the eye was first directed. The author explained this statement by means of a diagram which was exhibited. He had not been able to see the point of compensation close to the centre of rotation, where it doubtless must be, with a certain velocity, so that its locus must be in a curve.

On the Optical Study of the Retina. *By* Sir David Brewster, *K.H., F.R.S.*

There were two structures in the retina (hexangular and quadrangular) that could be exhibited by optical means, the one by the successive impulses of light, and the other by the action of faint light entering the eye, or produced within it, either from the duration of a luminous impression, or from a local pressure upon the retina. The first of these structures was best seen by the light of a white cloud, through the slits or apertures of a revolving disc, placed midway between its circumference and its centre of rotation, in order to protect the eye from light which did not pass through the slits. When the disc revolved rapidly the field of view exhibited neither colour nor structure, but merely a diminution of light. When the velocity had reached a certain point, the field of vision became yellowish white, then yellow and bluish. Occasionally the yellow had the form of a rectangular cross, between the branches of which were four dark spaces. With a diminished velocity the whole field became uniformly blue, and was now covered with the hexagonal pattern formed by deep-black lines, the lines being darker at the place of the *foramen centrale*. As there are no fewer than eight different layers in the retina, it was of great importance to ascertain the functions which they individually performed in conveying visual impressions to the brain, and it was only by optical means that this inquiry could be conducted. The anatomist had ably performed his part with the aid of the microscope, and it was probably from the improvement of this instrument chiefly that we could expect any further discoveries, unless the morbid anatomy of the retina should connect certain imperfections of vision with the condition of certain layers of the membrane. When the eye was left in darkness, by the sudden extinction of a light, there were several points at the margin of the retina which retained the light longer than the rest. There could be no doubt that these effects were produced by structural differences. In the case of the *foramen* the difference had been recognized by the anatomist, and was proved by the remarkable phenomenon of Haidinger's brushes, and by other optical facts, such as the instability and superior brightness of oblique impressions on the retina. We had, consequently, an optical principle which enabled us to explain the quadrangular structure he had referred to. It was not improbable, when we looked at the complete structure of the retina, and even of its individual layers, that the structure of each of them might be exhibited optically.

On Binocular Lustre. *By* Sir David Brewster, *K.H., F.R.S.*

The author commenced by stating that some years ago it was observed by Professor Dove that when the right and left eye figures of a pyramid, or other mathematical solid, the one drawn on a white, and the other on a dark ground, were inserted in the stereoscope, the solid in relief appeared with a particular lustre. Prof. Dove described the lustre as metallic; and in another place, where he described the two diagrams as drawn, the one with white lines on a black ground, and the other with black lines on a white ground, he stated that the pyramid in relief "appears lustrous, as made of graphite." Other observers described the lustres differently, some as resembling ground glass, and others as like paper darkened with a black-lead pencil, while Professor Rood regarded it as "recalling the idea of highly polished glass." In order to explain this phenomenon, Professor Dove remarked "that in every case where a surface appeared lustrous, there was always a transparent, or transparent-reflecting stratum of much intensity, through which we see another body. It is therefore externally reflected light in combination with internally reflected or dispersed light, whose combined action produced the idea of lustre. This effect," he elsewhere added, "we see produced when many watch-glasses are laid in a heap, or when a plate of transparent mica or talc, when heated red-hot, is separated into multitudes of thin layers, each of which, of inconceivable thinness, is found to be highly transparent, while the entire plate assumes the lustre of a plate of silver." To these examples of lustre, produced by thin plates not in optical contact, or if in actual contact, having different reflective powers, were to be added the following pearls, mother-of-pearl, pearl-spar, and composite crystals of calcareous spar, and decomposed glass of all colours. The cause of these various kinds of lustre, and of that of metals, had always been well known, and when binocular lustre attracted the attention of philosophers, it was natural to ascribe it to the same cause. Professor Dove did this, and considered the dark surface in the one picture as the dispersed light, and the white surface as the regularly reflected light, the dark surface being seen through the white surface. This theory of binocular lustre, he had reason to believe, was not satisfactory. The phenomenon was first observed by himself in 1843, under conditions of different forms than those under which it was subsequently seen in the stereoscope. Having adverted to a paper "On the knowledge of Distance given by Binocular Vision," published by himself in 1844 in the 'Edinburgh Transactions,' he said that with his knowledge of the phenomena he could not adopt Professor Dove's explanation of the lustre seen in the stereoscope by the union of figures on dark and white, or differently coloured surfaces. In order to test this explanation by other means, he combined surfaces that had no geometrical figures upon them, and he found that binocular lustre was not produced. This experiment seemed decisive of the question. He was led to infer from it that the lustre observed in the combination of right and left eye figures of solids was not due to the rays from a dark surface passing through a lighter one to the eye, but to the effect of the eyes in combining the two stereoscopic figures, and to the dazzle occasioned by the alternating intensities of the two combined tints, the impression of one of the tints sometimes disappearing and reappearing. He referred to an article published by Professor Rood, of Troy, on his (Sir David Brewster's) "Theory of Lustre," and which he disavowed, not having adopted any "theory of lustre." He had merely started an objection to Professor Dove's theory of binocular lustre, and given an opinion regarding its cause; and as the simple experiment on which he founded that opinion had been made by others with a different result, he thought it right to re-examine the subject with the assistance of other eyes than his own, and had obtained results which might be of use to those who were disposed to study the subject more elaborately.

Binocular lustre was a species of lustre *sui generis*. It was a *physiological*, not a *physical* phenomenon, and had no relation whatever to those varieties of lustre which arose from the combination of lights reflected from the outer and inner surfaces of laminated, transparent, or translucent bodies. He assigned various causes for the physiological character of the phenomenon, and then added, "If binocular lustre arises from a physiological and not from a physical cause, we must look for this cause in the operations which take place in the eyes of the observer when binocular lustre is distinctly seen. These operations are of two kinds. First, in combining geometrical or other figures to represent solids whose parts are at different distances from the eye, the optic axes are in constant play, not only in varying the distance of their focus of convergence, to unite similar points at different distances in the two diagrams, but in maintaining the unity of the picture by rapidly viewing every point of its surface. Secondly, when the two surfaces have different shades or colours, the retina of one eye is constantly losing and recovering the vision of one of them. Each optic nerve is conveying to the brain the sensations of a different tint or colour. The brain is therefore agitated sometimes with one of these sensations and sometimes with the other, and sometimes with both of them combined, and it is therefore not an unreasonable conclusion that, in the dazzle produced by this struggle of flickering sensations, something like lustre may be produced. In studying the subject of lustre there are some facts deserving of attention. In a daguerreotype, for example, of two figures in black bronze with a high metallic lustre, it is impossible by looking at either of the pictures to tell the materials of which they are made. No lustre is visible; but when the two equally shaded pictures are combined in the stereoscope, the lustre and true character of the material is instantly seen. Another instructive example is seen in the stereoscopic representations of a boy blowing a soap-bubble. The lustre of the watery sphere is not visible in either of the two pictures; but when they are combined, it is distinctly seen. In both these cases, and others of the same kind, tints of similar intensity are combined; and there is no ground fora ssuming that the two surfaces combined appear at different distances, and that the one is seen through the other, as in Professor Dove's theory.

Observations upon the Production of Colour by the Prism, the Passive Mental Effect or Instinct in comprehending the Enlargement of the Visual Angle, and other Optical Phenomena. By J. Alexander Davies.

The communication was intended to show that the doctrine of the decomposition of light is not the only possible explanation of colour, but that two causes may, in the way of possibility, be assigned to its production, of which the other is, that the rays receive certain affections or dispositions by their transit through a prism or other media. It was not affirmed that the present doctrine, which of course implies previous combination or composition, is not the probable one, but only that the idea of its necessary exclusiveness, as the only one which can philosophically be maintained, is a philosophical error. The difficulty of imagining decomposition in some cases, as, for example, when the solar rays pass through a piece of smoke-blackened glass, was referred to as affording some presumption for supposing that the production of colour by the prism is not occasioned by decomposition, and this especially when it is considered how difficult it is to conjecture how the prism effects the disintegration of the incident light. The equal difficulty appertaining to the hypothesis of disposition was also allowed; and it was shown that upon either explanation it must be granted that the incident rays pass to the second dyes of the prism, and back again to the first, before they are decomposed, or colours are otherwise produced, and that probably they arise from the backward transit of the rays, which is probably a species of retrogression. The phenomenon, that only the contours and internal lines and points of objects and pictures are coloured when seen through a prism, was accounted for by supposing that the rays proceeding from them are prevented from being recomposed by reason of the disturbance of the surrounding colour, which is not affected when seen through a prism, because the various rays are, by the law of chromatic aberration, united after being decomposed by it. The comprehension of the visual angle, or the determination of the prolongation of the angular space, in every case of reflexion and refraction, was set down either to passive mental action or instinct, and this on the ground of there not being any physical barrier, and from the fact that single vision alone is sufficient to produce this effect.

The light proceeding from luminous objects was stated to be accompanied with colour, and not colour *per se*: and as regards the intensity of colour, it was concluded that, as an example, a thin mixture of Indian ink is caused either by the very thin distribution of black particles, or white or almost white ones, more or less closely compacted; supposing which to be the case, the mixture is darkened with every increase in their compactness; of which explanations the former was considered to be the correct one.

The fact that black polished surfaces, however great the approximative perfection of the polish, reflect very little light, was set down to some yet undiscovered disturbance.

The last question noticed was the apparent increase in the size of the sun and moon when near and upon the horizon, which was illustrated by a description of an experiment, which consists in looking at a ball suspended by a fine silken thread, both when the external light does and does not fall upon the side next to the spectator, in the latter of which cases the ball appears larger than it would if looked upon in the hand; from which it was concluded that this supposition arises from its being supposed to be at a greater distance from the spectator than is really the case, and this consequent upon its dullness; and this explanation was applied to the sun and moon when in the positions mentioned, as being at any rate one cause of the phenomenon which may then be observed.

Presentations of Colour produced under novel conditions; with their assumed relation to the received Theory of Light and Colour. By Thomas Rose.

The author succeeded some years ago in perfecting a mechanical contrivance for measuring off flashes of artificial light, in due relation to the velocity of an independent revolving disc.

This apparatus was originally designed for no higher purpose than showing the ordinary, yet remarkable illusions of persistence of vision to a large company. Accident led to its employment in the illustration of phenomena of greater interest. It was found that a disc charged with eight intensely black circular spaces, equidistantly arranged around its circumference, presented some noticeable effects when subjected to the action of continuous daylight and intermittent artificial light. After repeated and careful experiment, it was ascertained that if, whilst the disc is in rapid revolution under a weak continuous daylight, flashes of artificial light are thrown upon it in rapid and regular succession, and at such intervals that the black circular spaces be held at apparent rest, several varieties of positive colour are seen. The black spaces show an intense blue in the central parts, melting towards the inner circumference into lighter blue, and towards the outer circumference into green; and they appear to lie upon a zone presenting intense orange in the centre, and lighter orange and yellow at the inner and outer circumferences. Other discs, in which the black circular spaces vary in diameter and occupy lesser portions of the zones containing them, were observed to give modified analogous effects. There was an evident law in the action. The colours were obviously dependent on the relative amounts of black space and white surface in the zones. As the black spaces were reduced, the colours ranged from dark blue to light green, and the separating intervals of whiteness, of greater or lesser width, took all tints, from intense orange to the faintest yellow.

The author deemed it worthy of especial remark, that all these presentations of colour were produced at pleasure under uniform conditions of action, and that they were so strongly and unequivocally expressed as to affect all eyes alike. This he thought made separation between them and other colour-effects that are merely physiological phenomena.

He was thus led to assume that his experiments touched the question—*Is light simple or compound?* and after much thought, it did appear to him that the resulting phenomena found consistent explanation in the assumed homogeneity of light, but presented difficulties when brought into relation with the received doctrine.

By a variety of experiments, carried on over a period of more than six years, Mr. Rose had been brought to favour the idea that what we name colour, is only the various affections of the optic nerve by a greater or a lesser quantity of light radiating from a focal point in an imperfect reflector. It is obviously impossible on this occasion to trace the steps by which he was led to form this conclusion. All that can be permitted, is to state briefly, and in general, the application of his views to the phenomena under consideration. When the disc is in rapid revolution, the weak continuous daylight keeps it constantly before the eye, but the intermittent light presents the black spaces continually in the same areas. Now the black spaces are assumed to have no part in the phenomena, except as absolute negations of light, and all the effects are referred to the distribution over an entire zone of the light of those portions of the zone not occupied by the black spaces. The nebulous ring produced by rotation is assumed to be light so distributed in relation to space as to produce blueness; and when the intermittent light brings the black spaces to apparent rest, they give back to the eye no part of the flash, but simply present this diffused light of the zone. On the other hand, the white intervals between the black spaces receive the flash and give it back, so that they reflect light in such relation to area as is necessary for the presentation of orange. The black spaces being circular, the white intervals between them are wider at the outer and inner circumference of the zone than in the centre; and hence the diffused light varies in character, and manifests itself in the negations as blue, light blue, and green; and in the intervals as dark orange, light orange, and yellow.

Method of interpreting some of the Phenomena of Light. *By* William Thomas Shaw.

The Chromascope, and what it reveals. *By* John Smith, *M.A., Perth Academy.*

The author said that he had described at the Meeting at Oxford certain experiments exhibiting phenomena of colour, in order to elicit the opinion of philosophers as to the cause of the colours; that the opinions then given, and those which he has since met with have completely failed, in his opinion, to meet the difficulties of the question.

The experiments he considered demonstrated the true physical conditions of the two colours *red* and *blue.* If we take the expression "pressure in time," from Newton, to mean the *time* of *action* of a vibration of light, then the interval will mean the *time* of *reaction.* If two forces impinge on the eye at the same time, and if the one be at its maximum and the other at its minimum phase, these two forces will represent the two physical conditions of the red and the blue rays; for during a pulsation the one will be always keeping up its velocity, while the velocity of the other will be constantly diminishing. This the author illustrated by many examples, which were explained by appropriate diagrams and drawings, showing how the two forces were generated. He was also of opinion that the exhibition of colour was the only evidence by which we could deduce that two such forces were in existence, but when once deduced could be verified by reversing the experiment.

The Prism and Chromascope. *By* John Smith, *M.A., Perth Academy.*

In this paper the author said, that having, as he considered, demonstrated in his former paper, by experiments from the chromascope, the physical conditions of the two extreme rays of the prism, he felt himself authorized to extend the discoveries made by the chromascope to the illustration of the prism. That, by a legitimate process of reasoning, he thought he was justified in concluding that the same law was in operation in the chromascope and prism, although the processes were different. That this law explained, in the most simple manner possible, the cause of the colour of thin plates of soap-bubbles and such other phenomena. That these explanations all followed as logical inferences from the same law, without any additional supposition or amendment. But that, in whatever light this theory might be viewed, he considered that the experiments which he had described could not be solved by any other theory, while they enabled him to give a very rational explanation of the prism.

On the Panoramic Lens. *By* Thomas Sutton, *B.A., Lecturer on Photography at King's College, London.*

The lenses commonly used by photographers for taking views have this grave defect, viz. they include too narrow a field of view for a large and important class of subjects. The author has invented a lens which remedies this defect, and produces an optical image which includes an angular field of 100° and upwards in perfect focus to the extreme ends of the picture. This lens, which is an entirely new optical instrument, unlike anything else, he has called a "Panoramic lens," and will now describe.

Imagine, in the first place, a thick spherical shell of glass, having its internal spherical cavity filled with water; and then, since the entire sphere is not required, imagine a central zone of the glass shell removed, and its place supplied by the brass mounting of the lens.

When the above arrangement is fitted with a central diaphragm having a small central aperture, it is evident that the pencils of light which pass through it must be incident perpendicularly upon each of the four surfaces; therefore there is no such thing in this lens as an oblique pencil, the errors due to oblique incidence are completely avoided, and the image formed in every part by direct pencils.

The glass shell, being a lens with concentric surfaces, acts as a concave or diminishing lens, and has positive focal length; while the central sphere of water acts as a convex lens, and has negative focal length. The medium having the *highest* refractive and dispersive power is therefore made into a *concave* lens, while the medium having the *lowest* refractive and dispersive power, is made into a *convex* lens. It is possible therefore to render this compound achromatic by giving a suitable radius to the inner surface of the shell. The investigation is extremely simple, and the practical result very neat and convenient. It turns out that when light flint-glass is used, the lens is achromatic when the inner radius of the shell is about one-half the length of the outer radius. The combination may properly be called a symmetrically achromatized sphere. It is a valuable property of a sphere achromatized in this way, that its focal length is greatly increased, so that a large picture can be taken with a tolerably small lens.

The central diaphragm is another curious part of this instrument. It is evident that if it were merely furnished with a central circular hole, the sides of the picture would be less illuminated than the centre. To meet this inconvenience the central hole is made elliptical, and in front of it are placed two upright thin partitions, radiating from the centre, and looking like the open wings of a butterfly. These stop some of the light of the central pencil and make it cylindrical, and at the same time they make the side pencils cylindrical also, and of the same diameter as the central one. This simple contrivance answers perfectly in equalizing the illumination.

The image of distant objects, formed by a panoramic lens, lies upon the surface of a sphere which is concentric with the lens. But the objects of an ordinary view are not all distant ones, for the objects upon the ground are generally much nearer to the lens than those upon the horizontal line. It is found, therefore, that the best form of focusing-screen to meet the majority of cases which occur in practice, is a part of a cylinder having the same centre as the lens, and including about 30° below and 20° above the horizontal line. The panoramic picture therefore includes about 100° in width and 50° in height. The upright lines are straight, and the perspective strictly correct in all parts of the picture.

Collodion pictures are taken upon curved glasses, and the negatives printed in a curved printing-frame. The author has not found greater practical difficulty in working upon curved than upon flat glasses.

A complete set of Panoramic Apparatus, manufactured by Mr. Thos. Ross, and also a negative upon a curved glass, including about 100°, and a print from the same, were sent for inspection.

Microscopic Observations on the Structure of Metals. *By* H. H. Vivian.

It is well known that silver and malleable iron, when newly broken, give a very considerable reflexion of light from the fracture, and it has generally been understood that the structure was granular, or composed of crystals, and that the reflexion of light was from their angles. On examining specimens of the above-named metals with a microscope, however, the structure was discovered to be perfectly porous or cellular, and the reflexion of light seen was from the inner surfaces of the cells, which, though minute, were most brilliantly reflecting, especially when newly broken; and when the metal was bent a little in one direction before breaking, thereby presenting the sides of the cells to the proper angle, the reflexion was more fully seen than when the cells remained in their natural position. There is a slight difference in the size and number of the cells in different specimens of the same metal, but the general resemblance is remarkably constant.

In silver the form of the cell is somewhat oblong; but the cell is larger than that of copper or iron, and the system is more perfectly developed, that is, the internal communication from cell to cell appears to be more regular. The form of the cell in copper is spherical; but in some instances the cells seem to have pressed into the domains of each other, and their forms are therefore to some extent modified thereby.

Copper from different works may differ a little in the diameter of the cells, and consequently in the number contained, but the general range seems to be from 500 to 1000 in the linear inch. It should be remarked that a specimen of the "best select" copper is not any more dense and solid than a less pure metal, but, on the contrary, the partitions between the cells are exceedingly thin—so thin that there appear to be minute openings from each one to its surrounding cells; so that, as in the silver, there is an internal communication through the entire mass.

The cells in malleable iron are less regular in form and size, their inner surfaces being jagged and uneven, and less brilliant than those of silver and copper; but the best fibrous iron seems to be equally free from angular crystals, and, like them, shows a high degree of porosity.

This cell-system is only developed internally in the metals; the outer surfaces, whether they have been in contact with the mould, or exposed to the atmosphere, seem to be entirely destitute of them.

In conclusion, the author regards it as highly probable that the malleability, as well as the superiority of the above-named metals for conducting heat and electricity, may be owing to the perfection of their cellular arrangement.

Observations on an Iris seen in Water, near Sunset. *By* J. J. Walker, *M.A.*

In this communication, which might be considered a sequel to and illustration of a paper read by the author at the Meeting of the British Association at Aberdeen in 1859, a description was given of the observation of this Iris—both of the *primary* and, more partially, of the *secondary* hyperbolic bow—in the calm sheet of water presented by a widening of the Royal Canal near Dublin, about 5.30 P.M., on the 29th of September. The sun being then near the horizon, the form approximated to that of the rectangular hyperbola.

There was an Exhibition of Photographs in connexion with the meeting at Manchester, under the direction of a Local Committee.

Electricity, Magnetism.

On Spontaneous Terrestrial Galvanic Currents. *By* G. B. Airy, *M.A., D.C.L., F.R.S., Astronomer Royal.*

It being now a well-ascertained fact that spontaneous galvanic currents have in several instances prevented the working of the telegraphic wires, the matter had become one of so much importance that he had felt the necessity of steps being taken to ascertain the exact cause of these disturbing influences. With this view he had placed himself in communication with the telegraph companies, but had not been able to obtain much accurate information from them, probably in consequence of their officers not having the leisure to note down observations on the effects produced on the telegraphic wires. His wish was to have a constant registration of the effect of these galvanic currents, at the Royal Observatory, and he believed that all that was required to ascertain the causes of these spontaneous disturbances was the laying down of an insulated wire. The Government had acceded to his proposal, and he thought it his duty to state that on the part of the Board of Visitors there was the most anxious wish expressed that the object he had in view should be carried out. In all these instances the Government had acted towards him with the greatest liberality. He (the President) had been in communication with Dr. Lamont, of Munich, and had received the following communications from him on the subject, which he had thought it desirable to have printed for the members of the Association, but not necessarily for circulation amongst the public generally. In one of his communications Dr. Lamont said, "Since the beginning of last year I have been occupied with the investigation of the electric currents observed in telegraph wires, and have obtained various results; the most remarkable of which is this, that electric currents, or, as they may be more properly termed, electric waves, varying in direction and intensity, are constantly passing at the surface of the earth, and that these waves correspond perfectly with the variations of terrestrial magnetism; a wave directed from north to south producing an increase of westerly declination, and a wave directed from east to west producing an increase of horizontal force. I have employed wires of different lengths, and metallic discs of different sizes and at different depths underground: in all cases the currents are the same; but their intensity depends on the size of the discs and the length of the wires, or rather, the distance at which the discs are placed from each other. A distance of 400 feet is sufficient if the discs are large enough. To show the effects satisfactorily, the instruments must be of a peculiar construction; ordinary galvanometers and magnetometers will not answer; besides, various other conditions are to be observed." And in another communication he stated that "The currents observed in telegraph lines are due partly to the agency of chemical causes (oxidation of the discs and other parts of circuits), partly to thermal causes (thermo-electricity, expansion, &c.), partly to terrestrial electricity. The variations of terrestrial electricity can only be obtained while the chemical and thermal causes remain constant. The effect of the chemical causes changes very slowly; the effect of the thermal causes can be considered as constant only in calm weather, and for very short intervals of time (say two or three minutes) when the wires are of moderate length and suspended in the air, for longer intervals if underground. I believe that lines above 1000 feet in length, if not underground, are of no use for the investigation of terrestrial electricity, because under all atmospheric circumstances the disturbances produced by thermo-electric currents will be too great." It appeared to him, with very great submission to Dr. Lamont, that they need not necessarily be bound or restricted to the limits which he suggested. As the disturbances affected long lines of telegraphic wires, it appeared to him that their attention ought more particularly to be directed to these long lines. He had brought the matter before the Section with the view of inviting discussion upon it. He should be happy to hear from the Section whether they were prepared to adopt the views of Dr. Lamont or his own, which, he might say, he had now power from Government to carry out. He should be glad if any gentleman would throw out suggestions upon the subject. He would not bind himself to act upon them, but at the same time they should have his best attention.

On the Laws of the Principal Inequalities, Solar and Lunar, of Terrestrial Magnetic Force in the Horizontal Plane, from observations at the Royal Observatory, Greenwich, extending from 1848 *to* 1857. *By the* Astronomer Royal.

The author described shortly the apparatus (being, in fact, that which was introduced by Mr. Brooke) by which the continued registers of magnetic direction and magnetic force are maintained. For the direction, a freely suspended magnetic bar carries a concave mirror that receives the light radiating from a fixed lamp, and causes it to converge upon a revolving barrel covered with photographic paper; the oscillations of the magnet cause the spot of light to oscillate lengthwise along the barrel; and as it is easy to compute, from the dimensions of the apparatus, the proportion that exists between a given swing of the magnet and the corresponding motion of the spot of light, the oscillations of the magnet at all times of the day may be measured accurately from the photographic record. These oscillations may be conceived as being produced by perturbing magnetic forces in the E. and W. direction, and the magnitudes of those perturbing forces may be inferred from the magnitudes of angular oscillation, by remarking that an oscillation of $1'$ corresponds to a perturbing force equal to $\frac{1}{3438}$ of the whole directive horizontal force. For the perturbing magnetic forces in the N. and S. direction, which exhibit themselves as changes in the magnitude of the horizontal directive force, the "bifilar apparatus" is used: a magnetic bar is strained into a position at right angles to the magnetic meridian, by suspension by means of two wires, which (their directions not being parallel) exert a torsion-force in opposition to the terrestrial magnetic force: when the terrestrial force increases or diminishes, it overcomes in a greater degree or yields to the torsion-force; and thus the changes of the magnitude of terrestrial directive force in the horizontal plane exhibit themselves by oscillations of the bifilar magnet, which are photographically registered in the same manner as those of the free magnet.

Having for every hour (or for any other intervals of time) the measures of the perturbing force in the E. and W. direction, and of that in the N. and S. direction, we can compound these two forces by the mechanical law of "composition of forces," and can assign the magnitude and the direction of the entire perturbing force (in the horizontal plane) which acts upon the magnet.

Upon discussing these perturbing forces, the following conclusions were obtained:

1. The mean annual diminution of western magnetic declination is about 7′·9; and the mean annual increase of horizontal directive force is about $\frac{1}{400}$th part of the whole horizontal force.

2. The diurnal inequalities diminish gradually through the period 1848–1857; the proportion of their magnitude at the end of the period to that at the beginning being about 3:5. This seems to show a general diminution of the power of the sun.

3. The diurnal inequalities are greater in summer than in winter, in the proportion of 5:3 nearly.

4. When the means for the 24 hours of the day are taken, the westerly declination is increased in summer, and the horizontal force is diminished, in a greater degree than corresponds to uniform change according to the law of conclusion No. 1.

5. When we form a curve by means of polar coordinates, drawing, from a zero point, lines in the direction of the perturbing force acting upon the north end of the magnet at every hour of the day, and with length proportional to the magnitude of that force at every hour (as derived from the mean of all the observations at each hour), an elliptical curve is produced, greatly extended in the direction of S.W. (which point corresponds to the disturbing force at 1 P.M.), and much less extended in other directions.

6. The great disturbance of the magnet occurs therefore when the sun is nearly vertical on the North Atlantic Ocean, and is directed towards the point to which he is nearly vertical.

7. Combining this conclusion with conclusions Nos. 3 and 4, the Astronomer Royal expressed himself as fully persuaded that the diurnal changes at Greenwich are produced by the attraction of the North Atlantic Ocean, when the sun radiates strongly upon it, for the north end of the needle; the attraction of the continent of Africa, when the sun shines upon it, being in comparison very small.

8. The curve mentioned in No. 5 has some distortions of singular character corresponding to the hours of night, which are not fully explained.

9. The Astronomer Royal then explained that the observations had also been discussed for discovery of the perturbations following the law of the lunar positions with respect to the meridian. The general result appeared to be that, twice in every lunar day, there is a force directed towards Hudson's Bay. There are some anomalies in the partial results; and the Astronomer Royal expressed himself as not very confident on the accuracy of the law, and not very distinct in his views of the explanation. The form of the general result bears a strong analogy with that of Tides of the Sea.

On the Formation of Standards of Electrical Quantity and Resistance. *By* Latimer Clark *and* Sir Charles Bright.

The object of this paper was to point out the desirability of the establishment of a set of standards of electrical measurement, and to ask the aid and authority of the British Association in introducing such standards into practical use. Four standards or units were considered necessary.

1. The unit of electromotive force, or tension, or potential.
2. The unit of absolute electrical quantity, or of static electricity.
3. The unit of electrical current, which should be formed by the combination of the unit of quantity with time. Such, for example, as the flow of a unit of electricity per second.
4. The unit of electrical resistance, which should be the same unit as that of current, viz. a wire which would conduct a unit of electricity in a second of time.

The necessity of the adoption of some nomenclature was also pointed out, in order to adapt the system to the wants of practical telegraphists.

On the Deposit of Metals from the Negative Terminal of an Induction Coil during the Electrical Discharge in Vacuo. *By* J. P. Gassiot, *F.R.S.*

When the electric discharges by an induction coil are made from platinum wires hermetically sealed in a vacuum tube as usually constructed, the wire which is attached to the negative terminal of the coil shortly assumes the appearance of being corroded: this arises from very minute particles of the metal having been disintegrated and separated from the wire, which particles are deposited on the sides of the tube in a lateral direction. If the wires are protected within the vacuum by being covered with glass tubing open at the end, but extending about one-eighth of an inch beyond the wire, it is the inside of this tubing that becomes coated with metal: but, exclusive of this lateral action, a portion of the negative discharge will be observed to obtrude from the glass tubing in the form of a luminous brush; this luminosity is very sensibly affected by a magnet, and can in this manner be made to impinge on different parts of the vacuum tube, and wherever it is thus impinged heat is always evolved. The above phenomenon of the deflection of the negative discharge was described in a paper communicated by me to the Royal Society; and as I was subsequently desirous to examine with greater accuracy the nature of the deposit thus obtained from the negative terminal, and particularly if it could be obtained in the same manner from other metals than platinum, I had an apparatus constructed in which the discharge could be directed on slips of glass: the apparatus was also so constructed that wires of different metals could be inserted, and in this manner I succeeded in obtaining deposits of the following metals, gold, silver, copper, platinum, zinc, iron, tin, lead (brass), magnesium, tellurium, bismuth, cadmium, and antimony: for many of these I was indebted to Mr. Matthiessen, who furnished them to me in a pure state. With gold, silver, platinum, tin, and bismuth, the deposit would take place in the state as now exhibited in about twenty-four hours' action; if the discharges were continued, the deposit became denser; and, as will be observed, in one or two instances the centre is crystalline. With reflected light a large surface exhibits the lustre of the metal; with transmitted light the outer portion is transparent, showing the peculiar colour of the metals—as gold, green; silver, bluish purple; platinum and tin, blackish grey. Tellurium, with the exception of antimony, I found disintegrated more freely than the other metals, while iron and magnesium were the most difficult; the deposit of the latter is scarcely perceptible. With aluminium wires I could not obtain any deposit after forty-eight hours' constant action; on one occasion I observed a faint trace on the glass, but in repeating the experiment with another wire no sign of any deposit could be obtained. Under the microscope the thin layer or deposit of metal is not resolved into any form, but appears as a mere film on the surface of the glass. From a brass wire terminal there was not any separation of the original metals. I had a tube constructed with two wires, both protected by glass tubing; a long slip of glass was inserted, so that the discharges from the + and the − terminals of the coil could be made with protected wires under the same conditions. The wires were of gold. The usual deposit took place at the negative; but after twenty-four hours' constant action not the slightest indication of any deposit from the + wire could be observed. With antimony a very peculiar effect was obtained: instead of the metal being deposited in a circular form, it spread nearly all over the glass and on the sides of the vacuum tube. I repeated the experiment by inserting slips of glass of sufficient length to reach beyond the terminals. Two of these glasses are on the table, and, if examined, it will be seen that the + discharge has apparently repelled the deposit as it formed from the negative wire, leaving the space somewhat analogous to the dark band which appears in the luminous stratified discharge. Whatever may be the cause of the difference in the action of the electrical discharge between the positive and the negative, the disruption of the metal in the latter is merely mechanical; the minute particles are disrupted by the force of the discharge, which at the negative meets with resistance, and which resistance, under certain conditions, is attended with considerable heating effects; for if the wires are thin, the negative invariably fuses, whether the discharges are made in air or in vacuo.

On a Probable Cause of the Diurnal Variation of Magnetic Dip and Declination. By Professor HENNESSY, *F.R.S.*

The author called attention to the researches of Mr. Faraday relative to atmospheric magnetism, whereby it appears that variations in the density and temperature of oxygen are always accompanied by corresponding variations in its magnetic properties. Variations in temperature of our atmosphere may occur not only horizontally, but vertically, and they may occur not only between columns of great extent, but even among extremely small portions of air. This question had been already submitted to the consideration of the Section in 1858 by Professor Hennessy, and an account of his experiments is contained in the volume published for that year. He had shown that certain abnormal *serrations* in the thermometrical curve which occur in May and June, and generally during the months of greatest sunshine, as exhibited by the photographical register kept at the Radcliffe Observatory, are explicable by the convection of minute currents of air. Thus the summer months of greatest sunshine correspond with the period of greatest inequality of temperature between small atmospheric masses. But the same months are also those during which diurnal magnetic variation is greatest. The hours of maximum magnetic deviation correspond with the hours of greatest thermometrical serration. This result appears not only from the facts disclosed by Sabine and Hansteen, but also from the facts disclosed in the paper just communicated by the Astronomer Royal.

On Permanent Thermo-Electric Currents in Circuits of one Metal. By FLEEMING JENKIN.

In the course of some thermo-electrical experiments, I was led to examine the effect of various distributions of heat in circuits formed by *one* metal. I verified the conclusion arrived at by Professor Magnus, that no distribution or movement of heat in a continuous and homogeneous piece of metal will produce a current of electricity. I also repeated, with some variations, the experiments of Seebeck and Magnus, which show that if one end of a wire be heated, the other remaining cold, a momentary or transient current of electricity will be developed when contact is suddenly made between the hot and cold ends; the direction of the current depending on the metal employed. I found that I could obtain permanent currents in the same direction from each metal, if I simply looped the two ends of the wire together and heated one of the two loops; and, moreover, that the current was usually much greater when there was a loose contact between the two wires, than when the two loops were tightly drawn together. It is to these currents, due to loose contact between a hot and cold wire of the same metal, that I wish to direct the attention of the Section.

I will first shortly describe the apparatus used, and the experiments which showed the existence and importance of these currents, and I will then endeavour to repeat some of the experiments before you. I used a reflecting galvanometer of the form constructed by Professor W. Thomson of Glasgow. A very light mirror, attached to a very small magnet hung inside the galvanometer coil, reflects the light of a lamp upon a scale about two feet off. Very small deflections of the magnet are distinctly shown by the movement of the reflected spot of light, while the slight inertia of the moving parts has great advantages when rapidly varying currents are to be observed. A common spirit-lamp was used to heat the wires, which were from 0·02 in. to 0·05 in. in diameter.

When two pieces of similar *copper* wire are connected with a galvanometer, and the end of one wire is heated, a momentary current flows from the hot wire across the joint to the cold one whenever they are suddenly brought in contact. While repeating this experiment, due to Seebeck and Magnus, I found that if the two ends of two such copper wires (being equally oxidized and annealed) were looped together and held tightly in contact, little or no current could be observed when one of the loops was heated in the flame; but when the hot and cold loops were *separated*, I observed a momentary current in the same direction as that produced when the hot and cold wire were suddenly *joined*—*i. e.* from heat to cold across the joint.

This fact, accidentally discovered, excited my attention, and led me to consider what the acts of making and breaking contact could possibly have in common. I reflected that when two wires are approaching or receding, they equally pass through points at every possible distance (within limits) one from the other. Thus I thought that the relative distance between the two wires might be the peculiarity which, being common to the two acts, might produce similar effects in each case. I therefore tried the effect of a loose contact between the two wires, resting the one wire very lightly on the other, instead of pressing or pulling the two together; a permanent current was at once produced, so strong as to hold the deflecting magnet of the galvanometer against its limiting steps. I then introduced resistance coils into the circuit for the purpose of reducing the deflection, but to my surprise it was not until I had added a resistance equal to that of 2000 miles of the Red Sea cable, or about 1000 miles of the common No. 16 copper, that I reduced the deflections within the range of my galvanometer.

The current could be maintained through this resistance for twenty minutes at a time—not perfectly constant indeed, but not wavering more than was inevitable from the varying pressure given by the hand to the two wires. The current was strongest when one end of the wires was white-hot, the other being dark red.

I varied the experiment in many ways, using different galvanometers and different copper wires, but always with one result. A tight contact gave a barely sensible current; a loose contact gave a current which could be maintained permanently equal to that which would be produced through a similar resistance by the eighth or tenth part of a Daniell's coil,—a strength sufficient to signal through a cable to America, if ever one be laid.

I next tried the same experiment with iron wires. Analogous results were obtained, but with one remarkable difference, namely, that the direction of the current was from cold to hot across the joint, instead of from hot to cold as in copper: moreover, a very sensible current was always observed in iron even when the two loops were firmly held together; it seems possible that this effect is only a residue of the effect caused by a loose contact, the hard oxide of iron precluding a perfect metallic contact between the loops. The effect is increased at least fivefold when a loose contact is made.

The maximum electromotive force to be obtained from iron is about one-twentieth that given by copper, and acts in the opposite direction.

Platinum gives no current with tight contacts; with loose contacts a weak current flows in the same direction as that given by copper. I must here warn any one disposed to repeat these experiments, that the resistance of the loose contact is itself considerable; and if the whole circuit, including the galvanometer, be of small resistance, the strongest deflection will be obtained with comparatively tight contacts; for although the electromotive force is increased by loosening the contact, the total resistance of the current may be increased in a still higher proportion, and the strength of the current will then diminish. This effect is exactly analogous to the well-known fact in voltaic electricity; for by the addition of small cells in series to a battery with large surface, the strength of the current may be reduced if the total resistance of the circuit be small, but will be increased if the total resistance be large. Thus the effects of loose contacts are best seen on a sensitive galvanometer with a large resistance in circuit.

These phenomena may apparently be due to a thermo-electric absorption of heat at the joint, or to a chemical effect in one of the wires, the air or oxide acting as an electrolyte. The opposite direction of the current in iron and copper, however, gives a reason for believing that chemical action is not the cause of the current. The decided effect obtained with platinum is another argument for this belief. It is moreover well established that any variation in the molecular structure of a metal causes one part to become thermo-electrically positive or negative with respect to the other; thus thermo-electric couples can be made of hard and soft wire of one metal, or of crystals arranged axially and equatorially, the current being then supported by the Peltier absorption and evolution of heat. Now discontinuity is the greatest possible change which can occur in the molecular structure, and it therefore appears not improbable that the currents due to loose contacts, or in other words to discontinuity, may be referred to the same cause as the currents due to varying temper or to crystalline structure,—that is to say, to absorption of heat where the change of structure occurs, heat being evolved in other parts of the circuit at a lower temperature. I hope soon to decide this question and others by further experiments in various media, with definite pressures at definite temperatures.

When various metals are combined, striking effects are produced, the strength of the common thermo-electric current from the joint being often increased fifty or a hundred fold when loose contacts are substituted for tight contacts. The direction of the current is also frequently reversed.

The results of these combinations are necessarily complicated, and require further experiment and analysis before publication. In the ordinary thermo-electric battery made from pairs of dissimilar metals, a very small proportion of the heat communicated to the joint is converted into electricity, which is therefore obtained from them at a great disadvantage. But considering the comparatively great intensity of the currents produced when loose contacts are adopted, it seems possible that by their means a considerable part of the heat used may be absorbed in the production of electricity, which would in that case be more cheaply obtained from heat, than directly from chemical action.

It is needless to allude to the consequences which would ensue should a cheap source of electricity be discovered; but without anticipating such important consequences from the discovery of the loose contact currents, they certainly seem a fit subject for further investigation. Meanwhile it is interesting to consider how, when two wires are tightly joined, the heat given them by the flame travels but a few inches slowly along them, producing all its sensible effects on objects in the immediate neighbourhood; whereas when those wires are moved asunder to an almost imperceptible distance, that same heat may in an instant be flashed as electricity through thousands of miles, reappearing distributed once more in the form of heat almost simultaneously in every part of the whole circuit.

On the Secular Changes of Terrestrial Magnetism, and their Connexion with Disturbances. By the Rev. H. Lloyd, *D.D., D.C.L., F.R.S., M.R.I.A.*

Of the various changes to which the direction and intensity of the earth's magnetic force are subject, unquestionably the most mysterious are those which, from their analogy to the slower changes of the solar system, have been denominated *secular*. No one has, as yet, offered even a plausible conjecture in explanation of these phenomena; while, on the other hand, it has been felt by all who have studied them, that their causes lie so deep, and are so closely connected with the hidden nature of the force itself, that the knowledge of them would, in all probability, unlock most of the secrets of terrestrial magnetism. For these reasons, any attempt, however imperfect, to add to our knowledge of the laws which govern them will probably be received with indulgence by magneticians.

It has long been known that, in addition to the changes which pass through their whole cycle of values in a day, or in a year, and which are thence called *periodic*, the magnetic elements at a given place are subject to changes of another kind, which continue for a long time in the same direction. It has been generally supposed that, for a limited number of years, the *rate* of these changes at any given place was either *uniform*, or else *uniformly accelerated or retarded*; so that they could be mathematically represented by a formula consisting at most of two terms, one of which was proportional to the time (measured from some certain epoch), and another to its square. In other words, it has been supposed that the *mean yearly values* of the magnetic elements were subject to *no fluctuations* of minor period.

This view, so far at least as concerns the secular changes of the inclination, has been completely disproved by Professor Hansteen. From the long and accurate series of observations of this element made by himself at Christiania for more than thirty years, Professor Hansteen has inferred that its progressive change from year to year sometimes increases, and at other times diminishes, returning to its former value in a limited time; and that, to represent it algebraically, it was necessary to add to its expression a term proportional to sin *mt*, *t* being the time reckoned from a particular epoch. In other words, the mean yearly value of the inclination is subject, according to Professor Hansteen, to a *periodical fluctuation*, whose length is $11\frac{1}{3}$ years, and which accordingly resembles the periods which have been ascertained to exist in the magnetical *changes*. Correcting for the *progressive* change, the inclination was found to be a *maximum* in 1828, 1840, and 1851, and a *minimum* in 1823, 1834, 1845, and 1856.

From a comparison of the Makerstoun observations with those made at other places, Mr. Broun has arrived at a similar conclusion with respect to all the magnetic elements; and he has pointed out the fact that the periodical changes of their mean yearly values are connected with the decennial period in the magnetic disturbances.

These important conclusions are fully confirmed by the Dublin observations. Assuming that the inclination decreases proportionally to the time, and comparing the results calculated according to this hypothesis with those actually observed, I have found that the *differences* clearly indicate a cyclical or periodic change. Applying the method of least squares to the observed results, the inclination at Dublin will be given, on the former supposition, by the formula

$$\theta = 70^\circ\ 21'{\cdot}95 - 2'{\cdot}76 \times n,$$

n being the number of the year reckoned from 1850. The values of the inclination calculated by this formula, as well as the differences between them and the observed results, are given in the following Table:—

Year.	θ (observed).	θ (calculated).	Differences.
1838.	70° 57′·57	70° 55′·09	+2′·48
1842.	44·07	44·05	+0·02
1843.	40·95	41·28	−0·33
1844.	35·96	38·52	−2·56
1845.	32·25	35·76	−3·51
1846.	32·65	33·00	−0·35
1847.	—	30·23	—
1848.	28·49	27·47	+1·02
1849.	27·00	24·71	+2·29
1850.	24·10	21·95	+2·15

There is therefore a *residual* phenomenon, plainly indicating a cycle or period, the *minimum* occurring in the beginning of the year 1845, as observed by Professor Hansteen at Christiania. I may add that the amount of the change at this epoch is such as to *mask* altogether the regular yearly decrease; in fact it led me at first to the supposition that the progression had been *reversed*, and changed from a decreasing to an increasing one.

The horizontal component of the magnetic force is a function of the force itself and of the inclination. It was therefore to be expected that it should manifest a corresponding fluctuation. This anticipation is fully proved upon an examination of the observations made with the bifilar magnetometer of the Dublin Observatory. The indications of this instrument at Dublin have been confirmed, in a remarkable manner, by the observations of intensity in absolute measure; and they are such as to afford most satisfactory conclusions with regard to the secular changes of that element. The mean yearly increase of the horizontal intensity at Dublin is 1322 millionths of the whole. It is, however, very far from uniform; on the contrary, it varies in magnitude from 641 to 1743 millionths, or nearly in the ratio of 1 to 3.

The annexed Table gives the absolute values of the horizontal intensity at Dublin, as deduced from the bifilar magnetometer and from the absolute observations. The first column contains the results of observation; the second the results calculated according to the hypothesis of a uniform progressive change; and the third the differences of the two. These latter show, very clearly, the existence of a cycle. The *maximum* occurs in the year 1844, and the *minimum* in the year 1848.

Year.	Intensity observed.	Intensity calculated.	Difference.
1841.	3·4635	3·4651	−·0016
1842.	·4694	·4695	−·0001
1843.	·4747	·4738	+·0009
1844.	·4793	·4782	+·0011
1845.	·4840	·4825	+·0015
1846.	·4876	·4868	+·0008
1847.	·4897	·4912	−·0015
1848.	·4936	·4955	−·0019
1849.	·4997	·4999	−·0002
1850.	·5052	·5042	+·0010

In the Supplement to the Makerstoun observations, published last year, Mr. Balfour Stewart remarks that the mean yearly values of the magnetic declination "exhibit some indications of a period in their value." The observations appear to show that the change of the declination from year to year, at Makerstoun, has increased from 1841 to 1855. When this change, and its variation (supposed to increase proportionally to the time) are computed and deducted from the observed results, the residual quantities clearly indicate the existence of a period, the *maximum* occurring in the year 1846, and the minimum in 1851.

The Dublin results exhibit evidences of a similar cycle. The probable value of the magnetic declination at Dublin, in any year, is given by the formula

$$\psi = 26^\circ\ 29'{\cdot}25 - 5'{\cdot}94 \times n,$$

n denoting the number of the year reckoned from 1850. And when the probable values for the several years of observation, computed by this formula, are deducted from those actually observed, the differences furnish, like the Makerstoun results, unmistakeable evidences of a period. But it is remarkable that the epochs of the maximum and minimum occur about a year earlier than at Makerstoun, the maximum taking place at Dublin in the year 1847, and the minimum at the end of 1842, or beginning of 1843. The total range of this periodical change at Dublin $= 2'{\cdot}24$.

It is impossible to avoid connecting these variations with the periods of magnetic disturbance. The difference of the observed results for any magnetic element, and the monthly mean corresponding to the same hour, being regarded as the effect of the disturbing cause, the mean of these differences, for any period, will serve as a measure of the *mean disturbance*. The following Table contains the mean yearly values of these quantities at Dublin, in the case of the magnetic declination, for the years 1840 to 1850 inclusive. The second column contains the differences between these yearly means and the means of all; they show very plainly the existence of the period whose laws have been so fully traced by General Sabine. The disturbance is greatly less than the mean in the years 1843, 1844, 1845, and greatly in excess in 1847, 1848.

Year.	Mean disturbance.	Diff.
1840	3′·25	+0′·54
1841	3·38	+0·67
1842	2·69	−0·02
1843	2·19	−0·52
1844	2·33	−0·38
1845	2·15	−0·56
1846	2·70	0·00
1847	3·06	+0·35
1848	2·99	+0·28
1849	2·69	−0·02
1850	2·36	−0·35

There can therefore be no doubt of the existence of a connexion between the cycles in the mean yearly values of the magnetic elements, and the disturbance cycle. It is worthy of remark, however, that the epochs of greatest and least declination *precede* those of greatest and least disturbance, while the corresponding epochs for the horizontal intensity *follow* them.

On an Electric Resistance Thermometer for observing Temperatures at inaccessible situations. *By* C. W. Siemens.

The Philosophical Magazine for January 1861 describes a method which I had had occasion to resort to for ascertaining the temperature of the interior of a mass of electric telegraph cable suspected of spontaneous generation of heat. Coils of copper of platinum wire, of known resistances, were placed between the layers of cable while coiling it, and leading wires conducted to an observatory. The temperature of the cable could at any time be ascertained by measuring the actual resistances of these coils by means of a Wheatstone's bridge arrangement, and comparing the results with the resistances of the same coils at a standard temperature. The electric resistance of a copper or well-annealed platinum wire, increasing in a very uniform ratio with increase of temperature, enabled me to determine the latter with a remarkable degree of accuracy.

In endeavouring to simplify the arrangement, I have succeeded in dispensing entirely with the Wheatstone's bridge, and, in fact, in reducing the observation to the mere reading of an ordinary mercury thermometer.

The apparatus consists of a differential galvanometer, and of a bath of water or oil, the temperature of which can be changed at will by opening one or other of two cocks, one supplying cold and the other hot liquid, an overflow pipe being provided to prevent accumulation. A battery of from four to eight cells is provided, besides a number of coils, each consisting of a certain length of thin insulated platinum wire enclosed in a sealed metal tube. These coils having been carefully adjusted, in the first instance, to offer an equal resistance at a fixed temperature, are connected with insulated copper leading wires, of comparatively large sectional arcs, the ends of which are brought to the binding screws of the apparatus, to be inserted, when required, in a circuit including the battery and one side of the differential galvanometer.

These "thermometer coils" are deposited at the places whose temperatures have to be observed, excepting one which is reserved for comparison with the others. This last-mentioned coil, connected by means of its leading wires so as to form an electric circuit with the battery and the other side of the differential galvanometer, is immersed in the bath before mentioned. This latter coil is enclosed in a sealed auricular chamber formed by an internal and external tube of copper or brass, which on being immersed immediately communicates the temperature of the bath to the coil.

It is evident that if the temperature of the bath be the same as that of the place where the thermometer coil under examination is deposited, the divided battery currents will meet, on each side, an equal resistance, and passing through the two helices of the differential galvanometer in opposite directions, will produce no visible effect upon the needle.

If, however, the temperatures of these coils should be unequal, the needle will be deflected by the preponderance of current in the cooler half of the divided circuit, showing by the direction of its deflection whether cold or hot liquid should be added to the bath to establish equilibrium of currents.

When this equilibrium is obtained, the temperature of the bath is observed by means of an ordinary mercury thermometer, and must necessarily be identical with the temperature at the distant stations where the coil under examination is deposited.

By dividing the *thermometer coils* into two portions, the apparatus is rendered applicable for observing wider ranges of temperature than can be attained directly by the mercury thermometer, and in this modified form it may be used for pyrometrical purposes.

The employment of equal and undivided coils in measuring ordinary temperatures is, however, not only the more simple arrangement but it has the advantage in its favour that the accuracy of the observation does not depend upon a uniform rate of variation of the resistance. The heat generated in the coils by the passage of the electric currents employed, affecting the two coils equally, is also completely compensated in using equal coils.

The late extensive conflagrations of hemp and other warehouses have suggested to me the idea of applying this method for detecting in such stores any spontaneous generation of heat. It also appears to me applicable in meteorological and other scientific observations where maximum and minimum thermometers are at present used.

On the Effect produced on the Deviation of the Compass by the Length and Arrangement of the Compass Needles; and on a New Mode of Correcting the Quadrantal Deviation. By Archibald Smith, *M.A., F.R.S.; and* F. J. Evans, *R.N., Superintendent of the Compass Department of Her Majesty's Navy.*

This was the substance of a paper lately read to the Royal Society, and about to appear in the forthcoming volume of the Philosophical Transactions. The following is a summary of the results obtained.

In correcting the deviations of a ship's compass in the usual way by magnets and soft iron, if it is necessary to bring the correctors so near the compass, and if the needle is of such a length that its length bears a considerable proportion to the distance of the correctors, an error is introduced which cannot be corrected in the usual way. When caused by magnets, this error is sextantal; when by soft iron, it is octantal. Mr. Evans, however, observed that this error did not arise when, instead of a single needle compass, an Admiralty standard compass was used. In this compass, instead of one needle there are four, arranged two and two at angles of 15° and 45° on each side of the central line—an arrangement adopted long ago in order to prevent the *wabbling* motion which a single needle card has when disturbed. And on submitting the matter to calculation, it appeared that the error in question was wholly corrected when, instead of one needle in the central line, there were two needles each at angles of 30° on each side of the central line, and four needles placed as in the Admiralty compass; the term involving the error having as a factor $\cos 3a$ in the first case, and $\cos \frac{3a+\beta}{2}$ in the second, where a and β are the distances of the needles from the central line. It is therefore recommended strongly that all corrected compass cards should be constructed in this way.

The second part of the communication was a new mode of correcting the quadrantal deviation. In all ships, with a very few exceptional cases, this error is positive. It may be corrected by cylinders of soft iron placed on each side of the compass; but when it is large, there are great practical difficulties in making the correction. It had been long ago observed by the late Capt. Johnson, R.N., that when two compasses are arranged as in the double binacle compass, they produce on each other a considerable deviation, being in fact a *negative* quadrantal deviation; and accordingly this arrangement had been prohibited in the Navy. It, however, occurred to Mr. Evans to apply this arrangement to correct the usual positive quadrantal deviation, and one pair of the compasses of H.M.S. Warrior are corrected in this manner. In this case likewise the needles should be arranged in the way above described.

Remarks on H.M.S. Warrior's Compasses. By F. J. Evans, *R.N.*

It may be considered interesting to the Meeting, as supplementary to the paper read by Mr. Archibald Smith, to receive a brief notice on the magnetism of the first of the great iron war-ships of the day, the 'Warrior,' and of the disposition of her compasses.

There is but little novelty in the arrangement of those on the upper deck, excepting that it has been deemed desirable to furnish two standard compasses, from the unavoidable proximity of the after one to a new feature which from the special character of the ship has been introduced, namely an iron-cased tower of rather considerable dimensions for holding riflemen, and of sufficient thickness to withstand the fire of heavy ordnance. This tower is placed on the quarter-deck, in the neighbourhood of the steering-wheel.

The magnetic character of the ship, as developed by the two compasses—before the rifle-tower was fixed—is quite in accordance with the received principles as due to the direction of the ship's head in building with reference to the magnetic meridian. The foremost compass, which is about $\frac{1}{3}$rd of the ship's length from the bow, had on the 10th of August last a maximum deviation of 16°, and the after compass, which is about $\frac{1}{3}$rd of the ship's length from the stern, a maximum deviation of 31°, the ship being built within 3° of the magnetic meridian (head N. 3° E.), and the points of no deviation consequently at north and south. The deviation of the after-compass had lessened 6° on the 24th of August, at which date the casing of the iron rifle-tower had commenced.

But it is not to these points I would now chiefly direct your attention, but to certain necessities arising from the novel structure of the ship, demanding, in so far as the compasses are concerned, serious attention.

In the fighting ships of what now may be termed a past generation, we did not seek for or expect invulnerability. In 1861 we demand nothing less, and "more iron" is the cry. It is clear from these new conditions that one compass at least, on which the ultimate safety of the ship may depend, should be equally protected from the fire of the enemy, in the event, which would most likely happen, of everything standing on the upper deck being swept away by the fire of the enemy.

For the management of the 'Warrior' under this probable contingency, an additional steering-wheel has been fitted within the great armour-protected space on the main deck: this space I need scarcely inform you is cut off from the ends of the vessel by massive iron bulk-heads. We are thus obliged, without reference to choice of position, to place a compass near this steering-wheel on the main deck, and surrounded by iron of massive character on every side, and above as well as below.

Under these circumstances we could not but expect deviations of an exaggerated amount, and particularly, from the large amount of horizontally placed iron from the two iron decks and their beams, a large quadrantal deviation.

From the few observations I have been enabled to make, owing to the constant progress of the fittings, this quadrantal deviation on the main deck is about 12°, nearly trebling in value quantities I have had to deal with in the other iron ships of the Royal Navy.

It must be familiar to those who have practically dealt with the subject of correcting ship's compasses by the antagonistic influences of magnets and soft iron, that 12° of quadrantal deviation is an enormous amount to deal with; and that the employment of soft iron correctors which might be usefully employed in the smaller values, becomes open to grave objections for the larger ones.

I have adopted for the 'Warrior's' main-deck compass the plan therefore alluded to by Mr. A. Smith, namely the compass cards on Mr. Smith's plan, and two compasses so placed close together as to destroy by their mutual action this 12° of quadrantal deviation, and correcting the polar magnet or semicircular deviation by *one* system of magnets placed in a vertical plane below, and in a central line between the two compasses, so that both are equally corrected at the same time. At the time of my observations this semicircular deviation was $3\frac{1}{2}$ points, or nearly 40° at the maximum.

I venture to hope that we have by this method overcome the more serious difficulties of disembarrassing the unfortunate compass, which is now so tortured in its action by the never-ending introduction of iron of all shapes, sizes, and quality around it; but I feel that unceasing vigilance is more than ever required in watching the compass under these conditions, and that the subtle agencies of the forces we employ will elude the control of unskilled hands.

The greatest difficulties I have experienced in making certain preliminary experiments, and what must happen practically in dealing with large compass deviations, are those due to delicacy of manipulation and workmanship: for example, the lubber lines of the compasses must be placed exactly parallel, and exactly in the fore-and-aft line of the ship; the centres of the compasses must be exactly in a line at right angles to the head of the ship; the adjusting magnets must follow the same accuracy of arrangement; and we are thus day by day approaching to the necessity of being forced to expend on an instrument, so common, but so valuable, and which unfortunately seamen in general, and I may venture to add, iron shipbuilders in particular, often treat so lightly, the same rigid accuracy of fittings and attention that are required in the more delicate instruments of the observatory. I may add that within the last few days I have been informed that the steering compasses of 'La Gloire' (the 'Warrior' of France) are placed *within* a similar rifle-tower on the upper deck. I am further informed by M. Dārondeau, who holds with respect to the French Imperial Navy a somewhat analogous position to my own in the Royal Navy of this country, that this is an unadvisable arrangement.

In concluding these brief remarks, I cannot but convey to the Meeting the deep debt that the seamen of all nations owe to the President for his long and patient investigation on their behalf, of the management of the mariners compass under difficulties; to him we are indebted for the first practical rules on the subject; and however opinions may have varied as to the uses of correcting magnets under the old condition of things, there can be no doubt that in the case of the 'Warrior's' main-deck compass, this system in its main features becomes an absolute necessity.

On the Photographic Records given at the Kew Observatory of the great Magnetic Storm of the end of August and beginning of September 1859. *By* B. Stewart, *A.M.*

The author remarked that the tendency of this great magnetic storm was to decrease the horizontal and vertical components of the earth's force, and that the disturbing force came in a wave, the period of which was seven hours. He contrasted this lengthened period with that of earth-currents, which is only a few minutes, and supposed that the change in the earth's magnetism is due to the absolute amount of a disturbing force, which is of a fluctuating character, and of which the fluctuations produce the earth-currents and Aurora Borealis, which are thus regarded as secondary discharges.

On the Amount of the direct Magnetic Effect of the Sun or Moon on Instruments at the Earth's Surface. By G. Johnstone Stoney, *M.A., F.R.S.*

In the Philosophical Magazine for March 1858, Dr. Lloyd showed that the observed disturbances of the magnetic needle, depending on the hours of lunar and solar time, follow laws inconsistent with their being due to the direct magnetic attraction of the moon or sun. Hence it might be too hastily concluded, from the absence of observed effects following the proper laws, that these luminaries are not magnetic. The design of Mr. Stoney's communication was to show that, though as highly magnetized as the earth, their direct effects would be almost inappreciable.

The maximum moment which the moon could impress on the needle was first ascertained to be $2\frac{MM'}{D^3}$, where M and M′ are the magnetic moments of the moon and needle, and D the interval between their centres. It follows from this that we may substitute for the moon a globe a metre in diameter of equally magnetized materials, and placed at such a distance as to subtend at the needle an angle equal to the greatest apparent diameter of the moon as seen from the earth's surface. By applying to the problem in this form the wonderful numerical data elicited from the observations by the genius of Gauss in his memoir on the magnetism of the earth, the greatest direct disturbance which the moon could produce, on the hypothesis of its being of materials as magnetic bulk for bulk as the earth, proves to be less than a tenth of a second of space on the declination-needle, and less than a twenty-seventh on the dipping-needle.

The observations with which these should be compared have been made at several stations. The principal part of the observed lunar-diurnal variation consists of a term depending on twice the lunar hour-angle, but there is also a small term containing the simple hour-angle. This latter is the one which, as Dr. Lloyd has shown, the direct action of the moon would affect, and General Sabine has determined its values at several stations scattered over the earth, in calculating the formulæ which best represent the observations. These values range (see the Introduction to the second volume of the 'St. Helena Observations') from 0″·48 up to 2″·04. There is therefore no ground for presuming, from the minuteness of the coefficient, that the moon is not of as magnetic, or even much more magnetic materials than the earth.

If the comparison with the earth be made mass for mass instead of bulk for bulk, the above disturbances must be reduced in the ratio of the moon's density to that of the earth, that is, to about two-thirds of the values already given.

The same method of course applies equally to the sun; and whether his magnetic moment be conceived to be greater than that of the earth in proportion to his mass, or in proportion to his bulk, his maximum influence will be even less than that assigned above to the moon; for he never attains an apparent size as great as the maximum of the moon, and his density is only about half that of the moon.

On Lightning Figures, chiefly with reference to those Tree-like or Ramified Figures sometimes found on the Bodies of Men and Animals that have been struck by Lightning. By CHARLES TOMLINSON, *King's College, London.*

Professor Poey has collected a number of such cases into a memoir, entitled 'The Photographic Effects of Lightning,' a second edition of which has been published at Paris during the present year. One of these cases is the following:—A boy climbed a tree to steal a bird's-nest; the tree was struck by lightning, and the boy thrown to the ground; on his breast the image of the tree, with the bird and nest on one of its branches, appeared very plainly. Mr. Tomlinson explains such cases by referring to breath-figures, and showed that when the discharge of a Leyden jar is received on a pane of glass, it burns away a portion of the organic film which covers all matter exposed to the air, so that when breathed upon, the moisture condenses in unbroken streams along the lines where the electricity has passed; while on the other parts of the surface the moisture condenses in minute globules, so that on holding the glass up to the light the figure is distinctly seen, so long as the breath remains on the plate. This figure resembles a tree, bare of leaves, and might (as the President of the Section afterwards remarked with reference to the diagrams exhibited) be taken for any tree in the world. In this figure we have a broad and somewhat rippled line of least resistance or path of the principal discharge, branching off from which are numerous ramifications, from each of which proceed large twigs, and from these smaller ones of great delicacy and beauty. It can be proved that when the discharge of a Leyden jar is thus received on glass, the jar sends out feelers in all directions to prepare the way for the line of least resistance, and this being accurately marked out, the principal discharge takes place. In some cases the discharge bifurcates and even trifurcates. If the glass presents too much resistance, the breath-figure consists of these feelers only; and these are the lines which produce the sensation of cobwebs being drawn over the face, which seamen sometimes describe as the forerunners of the ship being struck. The main trunk is hollow, and resembles in its structure the siliceous tubes known as Fulgurites. Mr. Tomlinson took this figure to be typical of the lightning discharge which strikes terrestrial objects, and objected to the stereotyped zigzag by which a stroke of lightning is generally represented. His theory is, that when a tree-like impression is found on the body of a man or animal struck by lightning, a portion of the fiery hand of the lightning itself has passed over the victim and left its mark. Several cases of this kind were described and discussed; but allowance must be made for the imagination of bystanders, which leads them to see in these ramified impressions "an exact portrait of the tree;" the blotches are taken for leaves, for a bird or bird's-nest, &c., as the case may be. Cases were also examined in which these tree-like impressions were referred by medical men to ecchymosis; other cases, in which the impressions of a horseshoe, of a nail, of a metal comb, of coins, &c., were found on the persons of the victims, were explained on the principle of the transfer of metallic particles from one conductor to another, as illustrated by the well-known experiment of M. Fusinieri. Mr. Tomlinson rejected the photo-electric theory, by which M. Poey attempted to account for the production of all these figures.

Meteorology.

On the Causes of the Phenomena of Cyclones. By I. Ashe.

On the supposed Connexion between Meteorological Phenomena and the Variations of the Earth's Magnetic Force. By John Allan Broun, *F.R.S., Director of the Trevandrum Observatory.*

In the 'Comptes Rendus' of the French Academy of Sciences for May 6, 1861, a note appeared by Father Secchi, Director of the Observatory of the Roman College, on the connexion between meteorological phenomena and the variation of the earth's magnetic force, as shown by the bifilar magnetometer at Rome. The results of Father Secchi's discussions appeared to me extraordinary; for though no careful examination of the subject has been published, yet the question had been examined by myself during the years that I directed the Makerstoun Observatory, both while observing, when during two years, on an average of eight hours daily, my eye was upon all the magnetical and meteorological variations, and afterwards while discussing the observations. In the latter case the simple method of projecting the simultaneous magnetical and meteorological observations employed by Father Secchi was also used, and had any slightly marked relation existed it would have been perceived at once. A particular discussion was made to determine if the variations of the *external* temperature had any effect on the bifilar observations, and the conclusion was that they had none*.

It would appear, however, from Father Secchi's discussion of the Roman observations, that the horizontal force of the earth's magnetism increases when the north wind blows and the barometer rises at Rome, while it diminishes when the south wind blows and the barometer falls; the two latter phenomena, it is well known, are connected with each other and with a rising temperature, while the two former are connected with a falling temperature. Had the variations of intensity to be explained been small, this last relation would have been taken by me as an explanation of the whole discussion, especially as the temperature-coefficient indicated for the Roman bifilar ($\frac{8}{100,000}$ of the whole horizontal force †) is less than half the average coefficient for bifilar magnets. Observations uncorrected, or insufficiently corrected for temperature would give just such results as those obtained from the Roman bifilar. The variations of force it seems, however, are too large to be explained by any such error ‡; and my own unpublished negative conclusions, however satisfactory to myself, cannot be accepted by others in opposition to results so positive as those contained in the paper under consideration. I have in consequence undertaken a special discussion of the observations of the bifilar magnetometer and of the anemometer made at Makerstoun in Scotland in the year 1844 §.

Before entering upon this discussion I should allude to an objection to Father Secchi's results, which exists in the conclusions of a paper by me on the horizontal force of the earth's magnetism, lately printed in the 'Transactions of the Royal Society of Edinburgh' ‖. From this paper it appears that generally, when the daily mean horizontal force diminishes at one point on the earth's surface, it diminishes simultaneously, and by nearly the same amount, at all other places (the discussion includes stations between 55° north and 42° south latitude); the same

* Trans. Roy. Soc. Edinb. vol. xviii. Introduction.
† Comptes Rendus, lii. p. 907. ‡ Ibid. p. 907.
§ Trans. Roy. Soc. Edinb. vol. xviii.
‖ Ibid. vol. xxii. p. 511.

holds for an increase of force. The earth therefore appears to act as a whole, as a great magnet, the increase or diminution being in proportion to the intensity at the given point. This fact is wholly opposed to an explanation which would attribute an increase or diminution of force to a purely local phenomenon, such as the direction of the wind, as may easily be shown; for if, while relating the direction of the wind at Makerstoun to the horizontal force at the same place, we also relate it to the horizontal force at some other place where the direction of the wind is known to be very different, and if the same, or nearly the same, result is obtained for the horizontal force at both places, we may be satisfied that the result, *whatever it may be,* is unconnected with the direction of the wind. For this end I have chosen as a second station Singapore, nearly on the equator (1° 19′ N. lat., 6^h 45^m long. east of Greenwich).

In a discussion of this kind, where the results obtained by others are disputed, it is necessary to state distinctly the methods employed: this I shall now do. The hourly observations of the bifilar magnetometers at Makerstoun and Singapore for 1844 having been corrected for temperature*, the monthly mean corresponding to each day in the year (that is, having that day for its middle point) was obtained for each place: this monthly mean includes the annual and secular change corresponding to the given day; and when it has been compared with the corresponding daily mean, the difference (+ if the daily mean were the greater, − if the lesser) will depend upon other causes. These differences were obtained for each day of 1844 on which observations were made. The approximate mean direction and mean pressure of the wind (in pounds on the square foot of surface) at Makerstoun were also obtained for each day of the year. In order to render the results comparable with those obtained by Father Secchi, the winds were included in the four heads, South, East, North, and West; the days of intermediate directions (as N.W.) being entered under the two principal heads (as north and west) with half weights only. For purposes of comparison the winds were separated into two classes—that of weak winds (daily mean pressure less than $\frac{1}{5}$ of a pound), and that of strong winds (daily mean pressure $\frac{1}{5}$ of a pound and upwards).

The following are the results of this discussion; and that a comparison may be made at once with those of the Roman Observatory, I shall first give the number of days for which the horizontal force was greater or less than the mean for each of the four winds.

Direction of Wind, Makerstoun, 1844.	Makerstoun bifilar, 1844.		Singapore bifilar, 1844.		Direction of Wind, Rome, 1860.	Rome bifilar, 1860.	
	Above mean days.	Below mean days.	Above mean days.	Below mean days.		High or rising days.	Low or falling days.
South	39	39	$34\frac{1}{2}$	$43\frac{1}{2}$	South	20	81
East	30	$16\frac{1}{2}$	28	$17\frac{1}{2}$	East......	9	22
North	$27\frac{1}{2}$	$29\frac{1}{2}$	29	29	North	119	17
West	$63\frac{1}{2}$	49	$61\frac{1}{2}$	51	West	42	21

Father Secchi's numbers are placed alongside for comparison.

It will be seen, first, that at Makerstoun, for a south wind the number of days for a high bifilar was just equal to the number of days for a low bifilar, and that nearly the same conclusion holds for the north wind; second, that both east and west winds show an excess of days with a high bifilar. The results for north and south winds, then, are quite opposed to those from the Roman Observatory, and the only case in which a similarity exists is that of the west winds; but that this coincidence is wholly accidental is evident from the corresponding result for Singapore. Indeed the numbers for Singapore agree generally very nearly with those of Makerstoun, the differences being explicable in most cases by days for which the daily mean bifilar was but slightly *plus* or *minus* of the monthly mean.

If we now consider the numbers under the two heads of weak and strong winds, we shall obtain other grounds for concluding that the results, such as they are, are independent of the direction of the wind.

* See Trans. Roy. Soc. Edinb. vol. xxii. pp. 484, 550.

Direction of Wind at Makerstoun, 1844.	Makerstoun bifilar.				Singapore bifilar.			
	Weak winds.		Strong winds.		Strong winds.		Weak winds.	
	Above mean days.	Below mean days.	Above mean days.	Below mean days.	Above mean days.	Below mean days.	Above mean days.	Below mean days.
South....	15	24	24	15	15	24	19½	19½
East	14½	6	15½	10½	10½	9	17½	8½
North....	8½	14	19	15½	10	12½	20	13½
West	18½	16	45	33	17½	17	44	34

If we examine first the numbers for Makerstoun, we perceive that for weak south winds there is an excess of days when the horizontal intensity was below the mean, while for strong south winds just the reverse was the case; a similar opposition is shown for weak and strong north winds. The east and west winds give more consistent results; but that the opposition in the former cases and the agreement in the latter are independent of the force or direction of the wind, will be evident on examining the corresponding numbers for Singapore.

As in this discussion many of the days noted may refer to differences of horizontal force very little above or below the mean, and as these days of slight difference have the same weight in the above tables as days of great difference, we shall avoid what is objectionable in this method by considering the *mean* of the positive and negative differences of intensity at both places for each wind at Makerstoun; these are included in the following scheme, where the quantities are in ten-thousandths of the whole horizontal force at the respective places.

Direction of wind at Makerstoun, 1844.	Mean differences of bifilar, Makerstoun.			Mean differences of bifilar, Singapore.		
	Weak winds.	Strong winds.	All forces.	Weak winds.	Strong winds.	All forces.
South	−1·93	+0·20	−0·87	−0·75	+0·10	−0·33
East	+0·87	+0·88	+0·88	+0·13	+0·66	+0·42
North	−1·02	−0·06	−0·43	−0·43	+0·41	+0·08
West	−0·55	+0·64	+0·28	−0·23	+0·16	+0·04

From this it appears that the horizontal force was, on the average, less than the mean for north and south winds at Makerstoun, and greater than the mean for east and west winds. The results for weak and strong winds are also generally contradictory, that for east winds being the only decided exception.

When we compare the quantities for Makerstoun and Singapore, we find the signs, with one exception, the same, but the amounts less at the latter than at the former station. This difference is due to the greater effect of magnetic disturbances on the means in the higher latitude. That this is the case may be easily shown in the present instance by omitting in the discussion the three days in 1844 having the greatest difference of daily mean from the corresponding monthly mean (namely March 29, April 17, and November 22). This may be done the more readily, since none of the three days is connected with any change in the direction of the wind, which was blowing between south and west. For these two directions, then, the following are the results, omitting the three days noted of greatest disturbance.

Direction of wind at Makerstoun, 1844.	Weak winds.		Strong winds.		All forces of wind.	
	Makerstoun.	Singapore.	Makerstoun.	Singapore.	Makerstoun.	Singapore.
South	−0·79	−0·63	−0·02	−0·01	−0·40	−0·32
West	−0·46	−0·26	+0·34	+0·23	+0·10	+0·07

Here the agreement for the two places is so much more marked as to confirm the explanation given as to the cause of the difference between the quantities for the two places. It may be necessary to repeat that the winds with which the Singapore bifilar is compared are not the winds blowing at Singapore, but those blowing at Makerstoun in Scotland.

The results, then, are not only opposed to those obtained from the Roman Observatory, but they are such as to prove that the direction of the wind is unconnected with these variations. It is scarcely necessary to remark that the final quantities obtained in the above discussions are very small, the greatest being less than $\frac{7}{10}$ths of one scale division of the Roman bifilar; in a discussion of a sufficiently large series they would probably entirely vanish. Should, however, further proof be required that the local meteorological phenomena are unconnected with the variations of horizontal intensity, it will be found in plate 28 of the paper previously cited on the horizontal intensity of the earth's magnetism, where it will be seen that the simultaneous variations of daily mean horizontal force from *hour to hour* at six places (Makerstoun in Scotland, the Cape of Good Hope, Trevandrum, South India, Singapore, Hobarton, Van Diemen Island, and Toronto in Canada) resemble each other, excepting in minute points and in cases of marked disturbance.

I should not terminate the examination of this question without noticing that Father Secchi has concluded that magnetic disturbances are predictors of change of weather at Rome; he has indeed given numbers which seem to show that there are most disturbances when the wind blows from the south at Rome. When it is remembered that magnetic disturbances are experienced simultaneously on all parts of the earth's surface, any connexion between them and the weather at Rome must appear extraordinary. For the strict examination, however, of this question, there are, however, several points to be taken into consideration, some of which it seems to me have been omitted by Father Secchi. First, we should decide on the definition of a day of disturbance; second, we should determine how many of these days occur in a fixed number (say a hundred) during which each wind blew; third, it should be remembered that the greatest mean magnetic disturbance occurs near the epochs of the equinoxes, and that the amount for perihelion is greater than for aphelion. As for these periods of the year, each place has a prevailing wind; the discussion for each place would give the greatest number of disturbances for these winds: thus at Makerstoun the prevailing winds were south-westerly, and the greatest number of disturbances occurred in 1844 with south and west winds; at Rome the prevailing wind at these epochs is perhaps southerly, and at Singapore it is probably westerly.

As I am unacquainted with the observations made in the observatory of the Roman College, I shall not venture to offer any suggestion as to the remarkable results which have been deduced from them.

On the Law of Universal Storms. By WILLIAM DANSON, *of Liverpool.*

In the course of his paper the author insisted on the soundness of the general views now prevalent regarding the theory of storms, and the regularity of their occurrence. He endeavoured to show that it was something like infatuation on the part of seafaring men ignoring these laws—captains and commanders, as well as ordinary seamen, included. It was a point of the greatest importance, at the present time, to consider whether it was not desirable to adopt improved means to secure the safety of traffic, leaving the rapidity of ships' passages as a secondary consideration; and supposing this view of the subject to be recognized, it was worthy of being taken into account whether the theory of what was now nautically known as the "great circle sailing" was not the best to be adopted by our mercantile marine captains generally. He knew that, in insisting upon the practical utility of recognizing this theory, he was in antagonism with the views of many experienced seamen, whose opinions were entitled to profound respect; but he nevertheless ventured to suggest, as worthy of the notice of the nautical public generally, that, in a great number of cases, ships whose captains had followed the "great circle sailing" theory had arrived safely at their respective destinations; whilst other vessels, under the same thermometrical and barometrical circumstances, but whose commanders had adhered to the hitherto received ideas of practical nautical navigation, had met with a fate which it would only be painful to dilate upon. Referring to the length and duration of storms, he said that the results of several of the most complete calculations indicated that, in the instances of storms, several of them had extended as far as 3600 miles, and travelled at the rate of 50 miles an hour, and that this is a moderate calculation.

Remarks on the Temperature of the Earth's Crust, as exhibited by Thermometrical Returns obtained during the sinking of the Deep Mine at Dukinfield. By Wm. Fairbairn, *Esq., LL.D., F.R.S.*

It is now more than ten years since a series of experiments were commenced to determine the temperature at which certain substances became fluid under pressure. These experiments had reference to the density, point of fusion, and conducting power of the materials of which the earth's crust is composed, and were prosecuted with a view to the solution of some questions regarding the probable thickness of the earth's crust. Contemporaneously with these, we were fortunate in being able to ascertain by a series of direct experiments, under very favourable circumstances, the increase of temperature to a limited depth in the earth's crust itself. These observations were obtained by means of thermometers placed in bore-holes at various depths, during the sinking of one of the deepest mines in England, namely, the coal-mine belonging to F. D. Astley, Esq., at Dukinfield. The bore-holes were driven to such a depth as to be unaffected by the temperature of the air in the shaft, and the thermometers were left in them for periods varying from half an hour to two hours. It is very difficult to arrive at accurate data on the subject of the increase of temperature as we descend from the surface to depths within our reach. On the contrary, the experiments hitherto made, give unfortunately somewhat conflicting results, and even in the same mine the rate of increase of temperature is by no means uniform. This is shown very clearly in the results obtained by Mr. Astley. It is scarcely probable, however, that the temperature in the mine shaft influenced the results, and we must therefore seek the cause of this irregularity in the varying conducting power of the rocks, arising from different density, and different degrees of moisture in the strata.

The following Table gives the general results obtained during the sinking of the shaft, which extended over a period of nearly ten years, from June 1849 to March 1859.

Table I.—Thermometric Observations in the Dukinfield Deep Mine.

Date.	Depth of the Pit.	Temperature of hole.	Time in hole, in minutes.	Quality of Measure, or Strata *.	State of bore-hole, and other remarks.
1848.	yds.	°	m.		
July 28.	5⅔	51	1440	Red rock	No variation.
1849.					
June 1.	231	57¾	30	Blue metals	Wet hole, water from sides.
,, 12.	234⅔	58	110	Blue metals	Dry hole, water from sides.
,, 16.	237	58	60	Blue metals	Dry hole, water from sides.
July 14.	239	57½	120	Blue metals	Dry hole, water from sides.
,, 16.	240	58	120	Blue metals	Dry hole, water from sides.
,, 27.	242	57½	120	Blue metals	Dry hole, water from sides.
Aug. 9.	244	58	120	Blue metals	Dry hole, water from sides.
,, 25.	248	58	120	Blue metals	Dry hole, water out of tubbing.
,, 27.	248	57¼	130	Blue metals	Dry hole.
,, 31.	250	57¼	150	Blue metals	Dry hole, in dust.
Nov. 14.	252	58	90	Blue metals	Dry hole, 5 men sinking.
Dec. 6.	256⅓	58	120	Blue metals	Dry hole, 5 men sinking.
,, 15.	262½	58½	90	Blue shale	Dry hole, 5 men sinking.
,, 22.	270	58	140	Bituminous shale	Dry hole, 5 men sinking.
1850.					
Jan. 9.	279¾	58½	180	Strong grey warrant earth	Dry hole, 7 men sinking.
,, 26.	286½	59⅛	110	Rock bands	Dry hole, 5 men sinking.
Feb. 11.	293	59½	60	Hard mine roof	Dry hole, 5 men sinking.
,, 19.	300	59⅞	180	Warrant earth	Dry hole, 5 men sinking.
Mar. 5.	309	59⅞	70	Purple mottled shale	Dry hole, 5 sinking.

* The terms in the column of remarks are those in common use amongst the miners.

TABLE I.—*continued.*

Date.	Depth of the Pit.	Temperature of hole.	Time in hole, in minutes.	Quality of Measure, or Strata.	State of bore-hole, and other remarks.
1851.	yds.	°	m.		
June 9.	358	$62\frac{1}{2}$	300	Warrant earth............	Dry hole, in dust, 5 men sinking.
Aug. 14.	373	64	61	Tender blue shale........	Dry hole, in dust, 6 men sinking.
Nov. 7.	403	65	360	Top shuttle mine roof...	Dry hole, in dust, 6 men sinking.
,, 19.	419	$65\frac{3}{8}$	120	Rock bands	Dry hole, in dust, 7 men sinking.
1852.					
Feb. 6.	433	$66\frac{1}{2}$	120	Black shale	Dry hole, in dust, 7 men sinking.
May 28.	446	67	120	Strong warrant earth....	Dry hole, in dust, 6 men sinking.
1857.					
Feb. 28.	$483\frac{1}{2}$	$67\frac{1}{4}$	75	Rock	Dry hole, in dust, 6 men sinking.
Mar. 7.	487	$67\frac{3}{4}$	75	Shale	Dry hole, in dust, 7 men sinking.
April 11.	501	$68\frac{1}{2}$	60	Rock	Dry hole, in dust, 7 men sinking.
May 6.	$511\frac{1}{2}$	$68\frac{3}{4}$	120	Blue shale.................	Dry hole, in dust, 7 men sinking.
,, 19.	$521\frac{1}{2}$	$69\frac{3}{8}$	135	Strong grit shale	Dry hole, in dust, 7 men sinking.
June 9.	533	$69\frac{3}{4}$	130	Warrant earth............	Dry hole, in dust, 7 men sinking.
,, 22.	539	$69\frac{7}{8}$	150	Blue shale	Dry hole, in dust, 7 men sinking.
,, 27.	546	$71\frac{3}{4}$	150	Coal and earth...........	Dry hole, in dust, 7 men sinking.
July 18.	555	$71\frac{1}{4}$	130	Grey rock.................	Dry hole, in dust, 7 men sinking.
Aug. 1.	563	$72\frac{3}{4}$	120	Red rock	Dry hole, in dust, 7 men sinking.
,, 15.	569	$71\frac{1}{4}$	120	Red rock	Wet hole, 7 men sinking.
Sept. 2.	578	$72\frac{1}{8}$	180	Red rock	Wet hole, 7 men sinking.
,, 19.	589	$71\frac{1}{2}$	90	Red rock	Wet hole, 7 men sinking.
Oct. 3.	597	$72\frac{1}{4}$	120	Grey red rock	Dry hole, in dust, 7 men sinking.
,, 17.	608	$72\frac{1}{4}$	150	Rusty mine roof	Wet hole, a little gas escaping.
,, 27.	$613\frac{1}{2}$	$72\frac{1}{4}$	180	Rusty mine floor.........	Wet hole, 7 men sinking.
1858.					
Mar. 22.	621	72	90	Strong grit shale.........	Dry hole, in dust, 7 men sinking.
,, 29.	627	$71\frac{1}{2}$	90	Dark blue shale	Dry hole, in dust, 7 men sinking.
April 23.	$645\frac{1}{2}$	$72\frac{1}{4}$	140	Gritty shale...............	Dry hole, in dust, 6 men sinking.
May 1.	651	$72\frac{1}{2}$	150	Gritty shale...............	Dry hole, in dust, 7 men sinking.
,, 19.	658	$72\frac{1}{2}$	120	Dark blue shale	Dry hole, in dust, 7 men sinking.
June 9.	669	$73\frac{1}{4}$	150	Bituminous shale	Dry hole, in dust, 7 men sinking.
,, 19.	673	$74\frac{1}{8}$	185	Grey rock..................	Dry hole, in dust, 7 men sinking.
July 17.	683	$75\frac{1}{4}$	180	Dark blue shale..........	Dry hole, in dust, 7 men sinking.
,, 21.	685	$75\frac{1}{2}$	180	Dark blue shale..........	Dry hole, in dust, 7 men sinking.
1859.					
Mar. 5.	717	75	1200	Black mine roof	120 yards down Engine Brow Works. Standing.

The increase of temperature with the depth, as exhibited in the preceding Table, is shown graphically in Plate I. The irregularly curved line takes a course which is approximately a mean of the results; the straight line is that which shows the increase of temperature on the assumption that it varies directly as the depth.

On examining the Table or the diagram, it will be seen that the experiments indicate some considerable irregularities; nor is this greatly to be wondered at, if we consider the difficulties of the inquiry, and the liability to error in assuming the temperature of a single bore-hole as the mean temperature of the stratum. At the same time it is not probable that the temperature in the mine shaft has in any degree affected the results, and we must therefore accept the observations as a whole, and attempt to ascertain their general bearing.

As to the rate of increase, they appear to confirm previous experiments, in which it has been shown that the temperature increases directly as the depth. The rate is at first rather less than this, afterwards somewhat greater, and at last again less; but, on the whole, as will be seen in the Plate, the straight line, on which the temperature increases as the depth, nearly expresses the mean of the experiments. The amount of increase indicated in these experiments is from 51° to $57\frac{3}{4}$°, as the depth increases from $5\frac{2}{3}$ yards to 231 yards, or an increase of 1° in 99 feet. But if we take the results which are more reliable, namely, those between the depths of e Deep Mine,

Table showing the increase of Temperature in sinking the Deep Mine

DUKINFIELD, near ASHTON under LYNE.

231 and 685 yards, we have an increase of temperature from 57¾° to 75½°, or 17¾° Fahrenheit. That is a mean increase of 1° in 76·8 feet. This rate of increase is not widely different from that observed by other authorities. Walferdin and Arago found an increase of 1° in 59 feet in the artesian well at Grenelle. At the salt-works at Rehme, where an artesian well penetrates to a depth of 760 yards, or rather more than the Dukinfield mine, the increase is 1° in 54·7 feet. MM. De la Rive and Marcet found an increase of 1° in 51 feet at Geneva. Other experiments have given an increase of 1° in 71 feet. In one respect the observations in the Dukinfield mine are peculiarly interesting, as they give the temperature in various descriptions of rock, which appear to prove what has hitherto been partially suspected, that the conducting powers of the rocks exercise a considerable influence on the temperature of the strata. If we add to this the influence of the percolation of water, we shall probably have a sufficient explanation of the irregularities observed in the experiments.

In Plate I. I have attempted to show graphically the results obtained between the depths of 231 and 717 yards. The dots show the actual experimental relation of depth and temperature, arranged on a Table in which the ordinates are depths and the abscissæ temperatures. Between these I have drawn a line of variable curvature, which expresses approximately the rate of increase in descending through the strata. Between the extreme indications which are most reliable I have drawn a straight line which expresses the theoretical rate, or a uniform increase of 1° in 76·8 feet of vertical descent. Beside the Table of curves is placed a section of the strata of the mine.

Since the above was written I have received from Dukinfield some further experiments obtained in the same manner in a new shaft which is being sunk at no great distance from the former. The following Table gives the results of these experiments:—

Table II.—Observations of the Increase of Temperature in the Dukinfield No. 2 Pit.

Date.	Depth.	Temperature Fahr.	No. of minutes in hole.	Strata.	Remarks.
1858.	yds.	°			
June 22.	167½	58	180	Blue shale	In this Table the thermometer was always placed in a dry sump hole, except on April 12, 1860, when the hole was wet. Up to April 30, 1859, five men were at work in the pit at the time of making the observations, and after that time six men.
,, 29.	174	57⅝	200	Blue shale	
July 21.	185½	58¼	200	Blue shale	
1859.					
Jan. 7.	239½	59	150	Blue shale	
,, 29.	254	58¼	140	Strong grey shale	
Feb. 17.	267	59½	150	Strong grey shale	
Mar. 5.	277	60	180	Strong grey shale	
April 2.	295	60	120	Huncliffe red rock	
,, 30.	308	60	130	Huncliffe red rock	
May 26.	315	61½	155	Huncliffe red rock	
June 16.	329	61¾	150	Grey shale	
Oct. 10.	358	62	150	Grey shale under T. Lane Mine	
Nov. 7.	382½	63½	150	Grey shale under T. Lane Mine	
,, 29.	398	63½	150	Grey shale under T. Lane Mine	
Dec. 11.	419	63¾	180	Bituminous shale	
1860.					
Feb. 6.	436½	65¼	120	Bituminous shale	
,, 29.	455½	66	120	Bituminous shale	
April 12.	467	66½	120	Grey rock	

This Table shows an increase of temperature of 1° Fahrenheit for every 106 feet descent.

From the above and similar observations we have evidence of the existence in the earth of internal heat, the temperature, so far as can be ascertained, increasing in the simple ratio of the depth. I do not, however, presume to offer an opinion as to whether this increase continues to much greater depths than we have yet penetrated, as observations upon this point are still imperfect. But, assuming as an hypothesis that the law which prevails to a depth of 700 yards continues to operate at still greater depths, we arrive at the conclusion that at a depth of less than two and a half miles the temperature of boiling water would be reached, and at a depth of 40 miles a temperature of 3000° Fahrenheit, which we may assume to be sufficient to melt the most refractory rocks of which the earth's crust is composed. If, therefore, no other circumstance modified the conditions of liquefaction, all within a thin crust of this thickness would be in a fluid state. This, however, is not the case. At these depths the fusing-point is modified by the pressure and conductivity of the rocks.

We know that in volcanic districts, where the great subterranean laboratory of nature is partially opened for our inspection, the molten mass, relieved from pressure, pours forth from volcanic craters currents of lava which form a peculiar class of rocks.

Besides this, it has been ascertained by experiment on soft substances, such as spermaceti, wax, and sulphur, that the temperature of fusion increases about 1°·3 Fahrenheit for every 500 lbs. pressure per square inch,—that is, in other words, that the temperature of fusion under pressure is increased in that ratio. If we assume this to be the law for the materials of the earth's crust, and correct our previous calculations in accordance with it, we find that we shall have to go to a depth of 65 miles, instead of merely 40 miles, before the point of fusion of the rocks is reached.

It must, however, be observed that Mr. Hopkins's later experiments with tin and barytes do not show such an increase of the point of fusion in consequence of pressure, and he is led to the belief that it is only in the more compressible substances that the law holds true.

Independently of this, however, Mr. Hopkins points out to me that in the above calculation it is assumed that the conductivity of the rocks is the same at great depths as at the surface. In opposition to this he has shown experimentally that the conducting power for heat is at least twice as great for the dense igneous rocks as for the more superficial sedimentary formations of clay, sand, chalk, &c. And these close-grained igneous rocks are those which we believe must most resemble the rocks at great depths below the surface. Now Mr. Hopkins shows that if the conductive power were doubled, the increase of depth, corresponding to a given increase of temperature, would be doubled, and we should probably have to descend 80 or 100 miles to reach a temperature of 3000°, besides the further increase which investigation may show to be due to the influence of pressure on the temperature of fusion.

Mr. Hopkins therefore concludes that the extreme thinness of the crust assumed by some geologists to account for volcanic phenomena is untenable. Calculations on entirely independent data led him to conclude that the thickness did not fall short of 800, instead of 30 or 40 miles. If it be so much, he is further led to believe that the superficial temperature of the crust is due to some other cause than an internal fluid nucleus. It remains a problem, therefore, which my friend Mr. Hopkins is endeavouring to solve, as to what is the actual condition of the earth at great depths, and the relation of terrestrial heat to volcanic phenomena.

Tidal Observations. *By* Rear-Admiral FitzRoy, *F.R.S.*

Since the publication of Dr. Whewell's invaluable essays on Tides, much additional information has been collected by the Admiralty, through various surveying expeditions in many parts of the world, respecting tides.

The accompanying volume of tide-tables shows to what extent our acquaintance with the facts of the subject goes at present.

However extended a knowledge of tidal facts may be *now*, compared with that of the earlier of those past years (some thirty), in which all maritime nations have benefited from light thrown on the subject by that "Essay towards an approximation," which enabled seamen to discriminate between features until then viewed in only a confused manner, and taught them clearly how and what to observe, there is still very much to be learned.

The useful, indeed now indispensable, yearly volume published by the Hydrographer, on the tides of the world, which, like the Nautical Almanac, is a text-book for the seamen of all nations, owes the truth of its principles, and great increase of its detailed facts, chiefly to Dr. Whewell, and, no doubt, he will cordially add suggestions, if he concurs in the belief that more still should be done.

In the central parts of the Pacific Ocean, and at numerous *isolated* points seldom visited for expressly tidal objects, exact details about the tides are wanting; but they are unlikely to be ascertained, except by a vessel employed specially for that purpose.

Tide-gauges, natural if not artificial, at such selected places, away from continents and near the deepest seas, should be watched adequately during a sufficient time, in order that their results, and a few comparative observations at known places, might enable Dr. Whewell to put the finishing hand to his comprehensive works on Tides, and to leave them completed for the general benefit of posterity.

On the Distribution of Fog around the British Isles.
By J. H. Gladstone, *Ph.D., F.R.S.*

Among the returns asked for by the Royal Commissioners on Lights, Buoys, and Beacons, and embodied in the Appendix of their Report laid before Parliament last session, was "The number of days in 1858 on which fogs were noted in the meteorological register." This question was asked in respect to each lighthouse or floating light in the United Kingdom. The author had gathered together the information thus obtained, and had constructed tables of 200 different sites, geographically arranged, with the frequency of fog at them in the year mentioned. 100 of these sites are in England and Wales, 48 in Scotland, and 52 in Ireland.

The following conclusions were drawn from the tabulated numbers:—

1st. The average number of days in 1858 on which fogs were noted in the different parts of the United Kingdom is:—

	On the coast.	At sea.
England and Wales	28	21
Scotland	22	17
Ireland	19	16
General average	24	20

2nd. The distribution of fog over different parts of a sea varies little, even though it varies greatly on different parts of the adjoining coast. Between the River Humber and the Straits of Dover there are 23 stations at sea which returned numbers ranging between 15 and 32, and nearly all included between 18 and 24; while the stations on the coast returned numbers irregularly distributed between 7 and 45, and in one instance 81. There are indications that fogs are about equally frequent in other parts of the sea surrounding England and Scotland, but only half as numerous on the west of St. George's Channel.

3rd. The frequency of fogs on the coast is in many places far less than on the neighbouring sea. Thus, on the southern and eastern coasts of England there are 14 stations where less than 15 days were noted. Every one of these is a station near the sea-level; and among them are the sandbanks at the mouth of the Thames, and the breakwaters. Promontories of low land are not very often visited by fogs.

4th. Two stations very near one another, but differing in their elevation above the sea, often differ widely in the frequency of fog, the lower site having generally the smaller number. Thus the station on the beach at Lowestoft gives 7 days, while that on the cliff gives 27. At North Shields, however, it is the reverse.

5th. When the land rises to a considerable height, and is so situated that it meets the south-westerly winds directly after they have traversed the ocean, a frequent deposition of moisture is the result—either "fog" or "cloud." The high points along the south and south-west coasts of England and Wales all give large numbers, especially the Start, 79 days; Needles, 75; St. Catherine's Point, 76; and Lundy Island (the highest station in England), 76. The lighthouse at the Needles has on this account been recently removed from the cliff to a low rock. In Ireland, the greatest frequency of fog noted in 1858 was at Ballycotton, 55 days, a high station on the southern coast. The west of Ireland appears not to be visited by fog so often as the west of England. The greatest number in the whole list is

126, at Barrahead, in the Hebrides; and this appears the more remarkable, as the neighbouring lighthouse at Skerryvore returns the very low number of 6 days; but the Skerryvore is a low rock many miles from land, while the station at Barrahead is the highest in the United Kingdom, on the southernmost point of a range of large islands, and near the Gulf-stream. The eastern side of the Hebrides is not foggy. The southernmost point of the Shetland Islands likewise returns a high number. The smallest number noted is at Troon in Ayrshire, viz. 4.

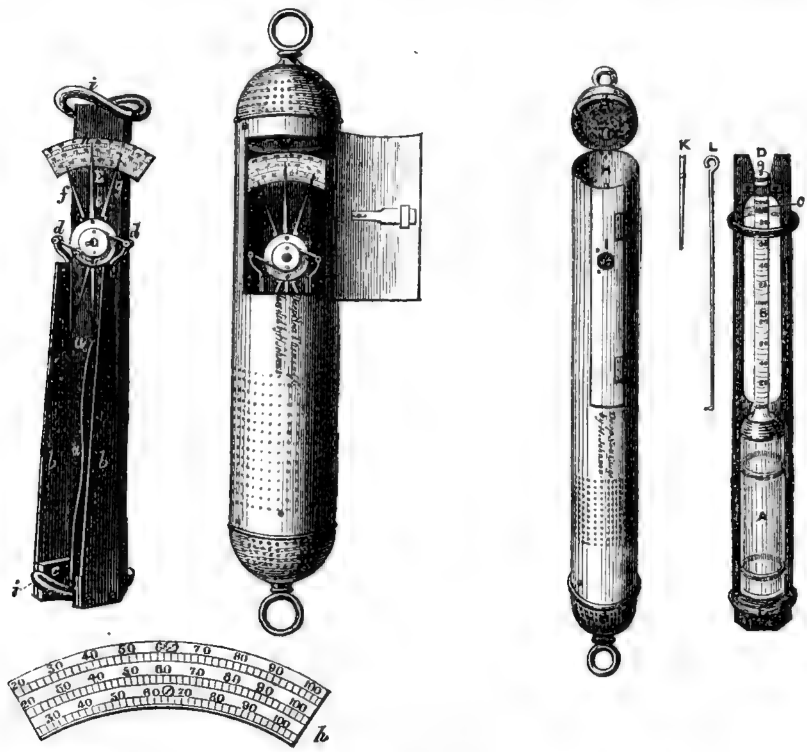
6th. Where a large area of sea is surrounded on most sides by land, fogs are infrequent—at least this seems to hold good on the coasts of the Moray Firth, the Minch, the Firth of Clyde and neighbouring sea, the Solway Firth, and Donegal and Sligo Bays. It is otherwise in the Bristol Channel. The Irish shore of St. George's Channel returns also small numbers, except at Dublin Bay.

On a Deep-Sea Thermometer invented by Henry Johnson, *Esq.*, 39 *Crutched Friars. By* James Glaisher, *F.R.S.*

The deep-sea thermometer is intended to be used in experiments made with the deep-sea pressure-gauge, to ascertain how much of the variation in volume indicated by the gauge is caused by variation of temperature.

In several experiments made by Mr. Glaisher in the year 1844 upon the temperature of the Thames water, at different seasons of the year, it was found that the indications of temperature were very materially affected by the pressure of water upon the bulbs of the thermometers used, even at the depth of 25 feet.

This circumstance demonstrated the importance of a thermometer for *deep soundings* without liability to derangement of indication from pressure of water, and led



A. The cylinder. B. Stem with graduated scale. C. Flat elastic ring or index.
D. Elastic stopper. E. Metal frame lined with caoutchouc.
F. Caoutchouc rings protecting glass gauge from concussion.
G. Caoutchouc rings, in the case, securing gauge in position.
H. Metal hook in the door of case securing the top.
I. Clasp to door, let in to avoid projection.
K. Vent, or grooved needle inserted with stopper.
L. Brass hook to draw up needles.

to the construction of the instrument now described, the indications of which are regulated by the lateral motion of compensation bars, composed of thin bars of two metals riveted together that expand and contract in different ratios with change of temperature. Upon one end of a narrow plate of metal about a foot in length (*a*) are fixed three scales of temperature (*h*) ranging from 25° to 100° Fahrenheit.

Upon one of these scales, as shown in the drawing on an enlarged scale, the present temperature is indicated by the point of a needle (E), which turns upon a pivot in its centre, and on the other scales register indices (*g*, *f*) are pushed by a pin on the needle (*e*) to the maximum and minimum temperatures, where they are retained by stiff friction.

To the needle are attached at equal distances from the centre, by connecting pieces (*d d*), the free ends of two compensation bars (*b b*), the other ends of the bars being attached by the plate (*c*) to the above-mentioned plate (*a*).

The motion of the needle is regulated by the lateral motion of these bars with change of temperature. In order to avoid disturbance of indication by lateral concussion, two bars are used in lieu of one bar only.

The compensation bars are composed of brass and steel, in the proportion of two-thirds of brass (which is the more dilatable metal) and one-third of steel, and have sufficient lateral motion to admit of legible scales of temperature, and also sufficient power to overcome the stiff friction of the indices.

The specific gravity of brass being 8·39, and that of steel 7·81, it is obvious that no pressure of water can have any effect upon the motive power of the bars, or upon the indications of temperature, as under hydraulic pressure equal to that of a depth of 6000 fathoms of water it acquires a density of 1·06 only.

The compensation bars are strongly tinned as a protection against sea-water, and the pivots on which the needle and indices move are strongly gilt.

In surveying expeditions this instrument may be serviceable in giving notice of a variation of depth of water, and of the necessity for taking soundings.

A diminution of temperature of water has been observed by scientific voyagers to accompany a diminution of depth, as on approaching hidden rocks or shoals, or nearing land, and also on approaching icebergs.

The instrument has been suspended by Mr. Glaisher on a thermometer-stand for a period of six months, and read daily in connexion with standard meteorological instruments, and during this time its readings were approximate to those of the best instruments.

The case of the instrument has been improved at the suggestion of Admiral FitzRoy, and now presents to the water a smooth cylindrical surface with rounded ends, and without any projecting fastenings.

On a Deep-Sea Pressure-Gauge invented by Henry Johnson, *Esq.* *By* James Glaisher, *F.R.S.*

In deep soundings the pressure of water is too great to admit of measurement by a highly elastic fluid in a small portable instrument. A slight degree of elasticity has been discovered in water itself, and which admits of a vessel of water being used as a measure of the amount of pressure at great depths.

Mr. Canton, whose experiments were communicated to the Royal Society on Dec. 16, 1762, found, in water subjected to the pressure of an additional atmosphere, a diminution in volume of one part in 21,740; and in water placed under a receiver he found an increase of one part in 21,740 when the air was exhausted.

Mr. Perkins found a diminution of $\frac{6}{100}$th parts in the volume of water subjected to a pressure equal to 1120 atmospheres, or about one part in 19,000 for one atmosphere.

A pressure-gauge of metal was exhibited at the Meeting of the British Association in 1860, and is described at page 203, consisting of a cylinder filled with water, with a solid piston or ram, with a graduated scale, and an index to mark the length of piston forced into the cylinder, compressing the water in it by the greater density of the surrounding water.

As, however, it is found that air-bubbles adhere to the inner surface of the metal cylinder, and the exclusion of air is important, a pressure-gauge is now exhibited composed entirely of glass, which is not liable to this disadvantage.

It consists of a cylindrical glass vessel with a finely graduated long stem or neck, within which are placed a flat elastic ring and an elastic stopper. When the water in the gauge is compressed, the stopper and ring are pressed down the stem towards the cylinder; and when it expands, the elastic stopper is pressed back, the elastic ring remaining as an index of compression.

Some few precautions are necessary before use, viz. the gauge should be well rinsed with boiled water for the purpose of preventing the adhesion of air to its inner surface. It should then be filled, to the top of the stem, with sea-water boiled to free it from air.

The elastic ring should now be inserted, and then the stopper, with a vent or small grooved needle at the side, to allow superfluous water to escape, and it should be pressed down the stem until its lower edge and the point or zero-line marked 2000 are coincident. The grooved needle should then be withdrawn, and the stopper will tightly fit the stem. The stopper should be slightly lubricated to prevent excessive friction.

On descending into water of greater density the water in the gauge is compressed until equally dense, and the elastic stopper and elastic ring are pressed down the stem towards the cylinder. On ascending to water of less density the water in the gauge expands, and the stopper is pressed upwards, leaving the elastic ring behind.

Upon regaining the surface after the experiment, the water in the gauge should press the stopper nearly back to its former position on the zero-line, a small difference being caused by friction.

The elastic ring marks the extreme compression at the greatest depth attained. This depth should be determined by the sounding line, to which the instrument should in these experiments be for some time attached.

The volume of the water in the cylinder and stem is considered to be divided into 2000 parts, of which the stem contains one-tenth or 200 parts; these are numbered from 1800 to 2000.

Each part on the stem may be easily read to a tenth, or a 20,000th part of the whole quantity.

A compression of sea-water of one part in 20,000 is caused by a pressure of 15·8 lbs. avoirdupois per square inch, or a depth of 35,456 feet, or nearly six fathoms.

The experiments of Mr. Canton and Mr. Johnson confirm this estimate of pressure, so that it appears to afford a basis for the compilation of tables for the comparison of pressure and depth.

Table of Variation in the Volume of Sea-Water, boiled to free it from Air, with Change of Temperature.

Degrees.	No. of Parts.	Degrees.	No. of Parts.	Degrees.	No. of Parts.	Degrees.	No. of Parts.
Fahr.		Fahr.		Fahr.		Fahr.	
86°	20000·	69°	19942·5	53°	19905·0	37°	19883·0
85	19996·	68	19940·0	52	19903·0	36	19882·5
84	19992·5	67	19937·5	51	19901·0	35	19882·0
83	19989·0	66	19935·0	50	19899·0	34	19881·5
82	19985·5	65	19932·5	49	19897·0	33	19881·0
81	19982·0	64	19930·0	48	19895·0	32	19880·5
80	19978·5	63	19927·5	47	19894·0	31	19880·0
79	19975·0	62	19925·0	46	19892·5	30	19880·0
78	19971·5	61	19922·5	45	19891·0	29	19880·0
77	19968·0	60	19920·0	44	19890·0	28*	19880·0
76	19964·7	59	19917·5	43	19889·0	27	19880·0
75	19961·5	58	19915·0	42	19888·0	26	19880·0
74	19958·25	57	19913·0	41	19886·7	25	19880·0
73	19955·0	56	19911·0	40	19885·5	24	19880·0
72	19951·5	55	19909·0	39	19884·5	23	19880·0
71	19948·0	54	19907·0	38	19883·5	22	19880·0
70	19945·0						

* A gentle motion kept up to equalize the temperature of the sea-water has prevented its freezing at 28°·5.

It is, however, very desirable that depths thus estimated should be tested by attaching the instrument to sounding lines, and that any necessary corrections should be made in the tables.

Such a comparison and correction would render the indications of the gauge valuable when strong currents make the use of the lead uncertain.

A correction is required for friction, yet to be determined, and a correction for the variation of volume with change of temperature, as shown in the preceding Table, which is based upon very numerous and accurate experiments.

On a Daily Weather Map; on Admiral FitzRoy's *Paper presented to Section A. relative to the Royal Charter Storm; and on some Meteorological Documents relating to* Mr. Green's *Balloon Ascents. By* J. Glaisher, *F.R.S.*

On the Cloud Mirror and Sunshine Recorder. By J. T. Goddard.

The Cloud Mirror was simply a mirror of a circular form with the points of the compass marked on its frame; this being presented face upwards to the sky, and having its centre correctly marked and placed horizontal with the north point of instrument towards the south meridian, enabled a person to observe the *direction* from which the clouds were moving. The Sunshine Recorder was a piece of photographic paper placed in the bottom of a box blackened inside, the top of which had in the centre a small circular hole, through which a slender beam of sunlight could be admitted to pass on to the photographic paper. When the sun did not shine, no mark was left on the paper; when it did, its varying diurnal course left a corresponding line on the paper, its position marking the hours of sunshine, and its breadth and depth of shade indicating the greater or less radiating power of the sun. By inserting a thick glass disc or plano-convex lens in the box, the number of hours' registry would be made equal to a summer day's sunshine.

On the Connexion between Storms and Vertical Disturbances of the Atmosphere. By Professor Hennessy, *F.R.S.*

As storms are usually preceded by the contact of masses of air of different densities and different degrees of elasticity, it follows that anterior to such storms a process of connexion may exist between the heterogeneous columns of the atmosphere. Under such circumstances, the sudden indraught of smoke in chimneys and the whirling about of light objects near the ground had frequently been noticed. The author endeavoured to make more precise observations by the aid of a vane, which shows the presence of upward and downward currents in the atmosphere, while also indicating the horizontal direction of the wind. During the winter of 1860–61, he found that most of the storms were preceded by more or less violent vertical movements of the atmosphere. Such movements were especially observable before the great gale of February 9*. The analogy between some of the vertical motions observed in the vane and those of the water-barometer formerly erected by Professor Daniell in the apartments of the Royal Society was pointed out, and fresh results were anticipated from the renewed erection of this kind of instrument by Mr. Glaisher. The general conclusion to which Professor Hennessy has been led, is, that during the comparative absence of horizontal motion in the air, energetic vertical currents may be grouped among the most certain symptoms of approaching disturbances on a grander scale.

On the Theories of Glacial Motion. By William Hopkins, *M.A., LL.D., F.R.S.*

The author first gave distinct definitions of terms designating those properties of bodies with which we are necessarily concerned in investigations connected with glacial phenomena, such as solidity, viscosity, extensibility, elasticity, and the like. According to those views, which rested on Dr. Tyndall's experiment of regelation, ice must necessarily be considered as *solid.* Proceeding on this hypothesis, Mr. Hopkins stated the pressures and tensions to which a glacial mass must be subjected at any internal point. He showed how the internal tensions would exactly account for the formation of open fissures or crevasses, according to the law which they were

* Proceedings of the Royal Irish Academy, vol. vii. p. 494.

observed to follow; and also that the internal pressures were exactly such as were consistent with Dr. Tyndall's views of the cause of the laminar structure of glacial ice, so far as it was a necessary condition, according to those views, that the structural lamina should be perpendicular to the direction of maximum pressure. Moreover he showed that the internal action was inconsistent with Principal Forbes's theory, which attributed the laminar structure to a differential motion of the contiguous lamina. He also explained the importance of the *sliding* of glaciers over the beds of their containing valleys, not only as the cause of a large portion of the whole observed motion, but also as increasing in a large degree the efficiency of the internal tension and pressure in producing the dislocation and crushing which were necessary for the general motion of the glacier.

On the Deficiency of Rain in an Elevated Rain-gauge, as caused by Wind. By W. S. Jevons, *B.A.*

When wind meets any obstacle, those strata of air which are near to the obstacle must be compressed, and must move with greater rapidity, just as a river moves most quickly in the narrowest parts of its channel. Thus, wind blowing against a house or tower has a greater velocity just above the summit of the building, than where there is no disturbance. Now a rain-drop, when falling through the wind, describes the diagonal of the rectangle of which the sides represent the velocities due to gravity and the impulsion of the wind. The path of a rain-drop then is inclined at an angle from the vertical direction of which the tangent varies nearly as the velocity of the wind. Two equal rain-drops, therefore, falling into a current of air at points where the velocity is not the same, will not pursue parallel paths. The one drop will either approach to or recede from the other, and the effect will be to increase or diminish the quantity of rain falling in the intermediate space. A diagram or a slight calculation will show this effect to be considerable, so that when a shower of rain falls through wind upon any obstacle, such as a house, a large part of the rain-drops will be blown beyond the obstacle by the increased velocity of the wind, and less rain will fall on the windward part of the top of the obstacle than elsewhere.

An ordinary rain-gauge, even when suspended in mid-air, will likewise act as an obstacle in the same manner, but in a less degree. Until, then, this effect of the wind upon the amount of rain collected in a gauge, either suspended in the air or placed upon a building, be properly allowed for, no conclusion can be drawn from any rain-gauge observations as to a real variation of the rainfall according to elevation.

Observations by Luke Howard, by Boase of Penzance, and by others clearly exhibit this influence of the wind. Other published observations, even those at the Greenwich Observatory, exhibit such great and irregular *individual* discrepancies, that no valid conclusion can be drawn from them. To take an average under such circumstances, it is argued, gives a purely fallacious appearance of uniformity and law.

The possibility of a real variation of rain with elevation is then treated on *à priori* grounds, and it is concluded that the condensation theory, first proposed by Benjamin Franklin, and the only one of the least validity ever offered to account for the apparent variation of rain, will never, under the real circumstances of the atmosphere, account for more than an almost infinitesimal increase of the rain-drops in the last few hundred feet of descent.

Observations on the coldness of rain when it reaches the surface oppose, instead of supporting, the theory of condensation, since the coldness of the rain-drop proves that it has condensed little or no vapour throughout its descent.

Arago's argument in favour of the increase of rain-drops near the surface, founded on the disappearance of the supernumerary rainbows near the ground, is also quite inconclusive, since the rain-drops probably become irregular in size by coalition, and would not become irregular by condensation of vapour.

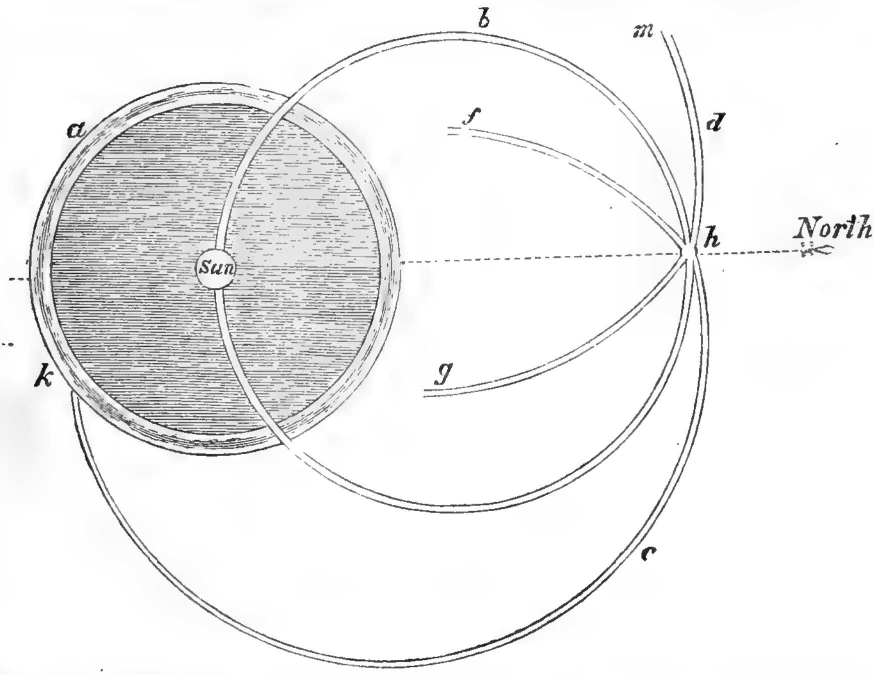
All observations by rain-gauges much elevated or exposed to wind are to be rejected as fallacious, and in accurate rain-observations it is recommended to place a very flat collecting vessel of considerable area in the centre of a flat surface upon the ground, in an open place, so that no appreciable obstacle may be opposed to the wind, and the splashing of the rain-drops within and without the collecting vessel may compensate one another. (See Lond. & Edinb. Phil. Mag. Dec. 1861.)

On a Solar Halo observed at Sydney, Cape Breton, Nova Scotia, August 13, 1861. *By* H. W. Crawley.

This day I witnessed, as well as all our household, a remarkable phenomenon. The sun appeared as if in *mourning*. At twelve o'clock I first observed it. An immense dark halo surrounded the sun, as dark as a thunder-cloud; the outer edge of it was iridescent, appearing like a circular rainbow. A ring of bright white light, of greater diameter than the halo, intersected it, passing through the sun; and two other rings of the same sort, but fainter, of still larger diameter, intersected the first ring and each other, in the manner I have attempted to show in the accompanying sketch, in which I have preserved, as nearly as I could judge, the relative proportions of the halo and rings to each other and to the sun. It was a bright day, the sun blazing directly overhead, out of a clear blue sky, but there were hard, electric-looking clouds in other parts of the sky; and from these were drawn out long, attenuated, fleecy, ribbon-like appendages, which all took a circular form, having the sun apparently for a centre. The halo and rings first appeared about an hour before noon, and continued as long after noon. Throughout the remainder of the day the clouds were in circular tiers or ranges about the sun, which became obscured. The weather for several days previously had been uncommonly cold and unsettled for the season, and the clouds rushed confusedly in all directions against each other; before which time there had been a protracted term of very hot and dry weather, thermometer ranging from 80° to 90° in the shade.

August 17.—The bad weather prevented my sending this letter over the water to the post-office last post-day (15th), there having been two days of a cold easterly storm of wind and rain following upon the before-described phenomenon, but to-day and yesterday all bright and warm again. (Signed) H. W. Crawley.

Appearance of the Sun with Halo and Rings at Noon, August 13, 1861.



The sun appeared as dazzling as usual, and could not be gazed at steadily; but the sunshine on the ground and surrounding objects was fainter, or in some way differing from its ordinary appearance.

a. Iridescent margin of the dark halo round the sun. *b.* Ring of white light passing through the centre of the sun. *c, d.* Two fainter rings of light, of which the interrupted or broken parts nearest to the sun (*f* and *g*) appeared to converge toward the sun and fade away. *h.* A node of light at the intersection of the three rings. *k.* This end terminated here. *m.* This end broken off, or faded away.

(I had no instruments, and am not certain as to the magnitude of the halo and rings, nor as to the centres of the rings *c* and *d.*)

Description of a Mercurial Barometer, recently invented by Mr. Richard Howson, *Engineer of Middlesborough-on-Tees.* *By* Peter J. Livsey.

This barometer consists of a straight tube, called in this paper "the tube," similar to that used for the common straight barometer, but somewhat longer, and a hollow stalk nearly the same length as the tube, but of such smaller diameter that it will pass up the bore of the tube and leave an annular space of about $\frac{1}{10}$th or $\frac{1}{8}$th of an inch. The lower end of the stalk is surrounded and united with a short tube called "the cistern," sufficiently large in diameter to allow the tube to pass into it and leave an annular space. When the barometer is in working order, "the tube" is suspended freely in a vertical position with its open end downwards, the stalk passing up the bore of the tube till the lower end of the tube enters the cistern; and the annular spaces between the stalk and interior of tube, and the stalk and cistern, are filled with mercury, the cistern containing sufficient mercury for the immersion of the lower end of the tube when the stalk and cistern are at their lowest position. The tube and cistern are filled with mercury to form a vacuum at the upper end of the tube, so that the pressure of the atmosphere alone will sustain the weight of the stalk, cistern, and mercury.

The stalk has a buoyant power sufficient to carry its own weight, the cistern, and the mercury in the cistern, at the lowest pressure of the atmosphere. The pressure of the atmosphere will be shown by this barometer, by the difference between the level of the mercury in the cistern and that in the tube, by the position of the top of the column in the tube, and by the position of the stalk and cistern.

Barometers may be made upon this principle, having a long range or movement for a small change of pressure, by which such changes may be measured with great delicacy; and this advantage, without the inconvenience of a very long scale, may be obtained by using weights which can be added or removed as required for, say, the whole inches, reading the fractions of the inch from the scale.

One advantage of this barometer is the comparatively small quantity of mercury required. Tubes of large diameter may therefore be employed, and thus instruments having great power and accuracy may be obtained, as a small change of pressure will be multiplied by the large area, and the power or change of pressure acting to produce a movement in the barometer will thus be great in proportion to the friction resisting the movement.

The formula for calculating the rise of the top of the column of mercury in the tube for any given increase of pressure is $R=\frac{TP}{G}+P$.

The formula for the movement of the cistern for any given rise, when the mercury extends above the stalk and fills the entire bore of the tube at the lowest pressure, is $\dot{R}=\frac{TP}{G}$; but when the stalk extends above the column of mercury and into the vacuum space, it is $\dot{R}=\frac{\dot{D}\dot{C}\times\dot{T}P}{G}$. The increase in the depth of the cistern is obtained by the formula $\ddot{R}=\dot{D}-\dot{R}$; when the top of the stalk is always below the mercury and it fills the entire bore of the tube, the depth of the cistern is uniform for all pressures. In the above formula R is the total rise of the top of the column in the tube for any given increase of pressure, $\dot{R}$ rise of cistern, $\ddot{R}$ rise of level of cistern, T area of the bore of the tube, G area of the glass or material producing displacement in the tube, P pressure in inches of mercury, C area of cistern, $\dot{C}$ area of cistern minus G, $\dot{T}$ area of annular space between interior bore of the tube and the stalk, $\overset{:}{D}=\frac{TP}{G}$. In these formulæ it is supposed that the tube, stalk, and cistern are perfect tubes or cylinders uniform in area throughout their entire lengths.

On the Great Cold of Christmas 1860, *and its destructive Effects.* *By* E. J. Lowe.

The author said that the excessive cold of Christmas 1860, near Nottingham, being perhaps as great, if not greater than had ever occurred in England since the invention of the thermometer, it appeared desirable to record so unusual a degree of cold, together with its destructive effects in the midland counties. Some idea of the fearful ravages amongst trees and plants might be gathered from the fact that not only had numerous branches of the oak been damaged, but in some instances large trees themselves had been killed. The summits of hills had escaped much of the ravages of the frosts that had been so seriously felt in the valleys. He gave a long list of the destruction of trees and plants as recorded in the report at the Highfield House Observatory, and stated that the destruction of birds and insects was also very great. One circumstance with regard to this excessive cold, which he recorded at the time, he wished to repeat. He alluded to large icicles which he had seen formed at the nose of a horse. Turning to the temperature, there were frosts every night from the 12th of December to the 19th of January, the temperature on the grass on the coldest nights being from 21° 5′ on the 18th of December, down as low as 17° 5′ on the 10th of January. At four feet above the ground the greatest cold was on the 24th of December, 0° 5′, and on the 25th −8·0. The mean temperatures of the coldest days were 13° 3′ on the 24th, 4° 0′ on the 25th, 22° 6′ on the 26th, 23° 6′ on the 28th, and 21° 7′ on the 29th. The greatest heat only reached 12° on the 25th, and only 16° in full sunshine. During this excessive cold weather he had delicate thermometers placed at various heights above the ground, up to 27 feet. These instruments were used constantly. The thermometers were all compared with the standard presented to him by the British Association. He named this, as he was aware that some meteorologists conceived that the records given were impossible for the climate of England. Nevertheless he had the confirmation of 27 instruments placed on and above the ground, and also on his observatory, and giving a temperature of from 7° to 14° below zero, according to the circumstances under which they were placed. He could vouch for the accuracy of the readings of his instruments; and as he had an equal number of mercurial and spirit thermometers, it could scarcely be possible for the temperature given to be far from the truth. Whatever might be the opinion as regarded the actual temperature, there could be no doubt as regarded the destruction, which exceeded anything remembered by the oldest person. In 1854 a temperature of 4° below zero destroyed many trees, but the destruction in 1860 was very much greater.

Letter from Captain Maury. (*Communicated by the Lords Commissioners of the Admiralty*).

Admiralty, September, 1861.

Sir,—I am commanded by My Lords Commissioners of the Admiralty to transmit to you herewith copy of a letter, dated April, 1861, from Commander Maury, of the United States, which has been referred to their Lordships by Her Majesty's Under Secretary of State for Foreign Affairs, urging the importance of an Expedition to the Antarctic Regions, for meteorological and other scientific purposes; and I am to request that you will lay the same before the proper Section of the British Association, at its Annual Meeting at Manchester.

I am, Sir, your obedient Servant,
W. G. Romaine.

The General Secretary of the British Association.

Observatory, &c., Washington, April, 1861.

My dear Lord Lyons,—You are no doubt aware that all, or nearly all the States of Christendom that use the sea, have practically agreed to unite in carrying on, through their Navies at sea, a series of observations for the improvement of navigation and the benefit of commerce, and that men learned in the physics of the sea and air have been appointed in Norway and Sweden, in Russia, Denmark, Holland, France, England, Spain, Italy, and Portugal, to take charge of these observations, and either to discuss them themselves, or so to dispose of them that they may be treated by experts and the results made known to all concerned; and that from the Bureaus established for this purpose in Holland, London, and Paris, highly important results have been already obtained and given to the world as the common property of all. These results, by rendering navigation less dangerous and speedy, have conferred numerous benefits upon all those of every nation who follow the sea.

Thus a sort of maritime and scientific confederation of the principal commercial nations has been practically formed, for the purpose of carrying on certain investigations concerning the physics of the sea, in which all the world has a stake.

During these investigations, it has fallen to my lot to be led, by the paths of induction thus opened, to certain conclusions that are of general concern—not indeed to the people of any one nation alone, but to all who own ships,—and which I beg to lay before you, with the hope that you will deem them of sufficient consequence to be brought to the notice of the Government you so worthily represent, to the end that such further steps may be taken in the premises as the increase of our knowledge concerning the planet we inhabit and the good of mankind may seem to require.

I may be permitted to remark, that though this system of research upon which we are engaged presents the most extensive combination that has ever been formed among navies, and though it gives employment to the largest corps of observers that has ever been known to unite in any one plan of physical research, yet it is almost literally without cost; at least the expenses are so divided between the observers and the public exchequers of the States concerned, that the chief expense consists in discussing and publishing the observations after they are made. In fact, the observers are quite willing to render their services upon the simple condition that they may have the free use of the results obtained. Thus all the great nations have been brought to unite and cooperate in a uniform system of physical research at sea.

In the course of these investigations, facts and circumstances have been brought to light which afford grounds for the belief that the Antarctic winter is by no means as severe as that of the Arctic. This belief, connected with the fact that there is about the South Pole an unexplored area that in extent can compass Europe more than twice, induces me to lay the matter before yourself and others at this time, trusting that by bringing the subject to such notice, as well as to that of my own Government and others equally interested and concerned, measures looking to further examination and exploration of those unknown regions in the South may be set on foot.

Reasons for believing the Antarctic to be much less severe than the Arctic winter, have been stated at some length in a work on the 'Physical Geography of the Sea and its Meteorology,' recently published in London; but as that work may not have fallen under your notice, I beg leave to call your attention to the Tables, Diagrams, and Plates in the accompanying Nautical Monograph, No. 2, on 'The Barometer at Sea,' still more recently issued by this office. Our observations on the barometer at sea are numerous and abundant. They reach from the parallel of 60° S. to the ice-bound seas of the North; they are for all seasons, months and days of the year. They have been made over and over again; some by German, some by Russian, some by English, Dutch, French, Spanish, Danish, Swedish, Portuguese, Italian, Austrian, Chilian, Siamese, Sandwich Islands, Brazilian and American navigators. They have been repeated and multiplied by so many, by such factors, and so often, that they leave but little room for doubt as to the approximate mean pressure of the atmosphere on every square foot of ocean surface within the range of modern navigation. They enable us for the first time literally to gauge and weigh the atmosphere that rests upon the sea; they also afford us data for computing its pressure upon every square foot of sea surface from pole to pole. A patient discussion of these observations has revealed a wonderful degree of atmospherical attenuation within the Antarctic Circle. They indicate that the average quantity of air superincumbent upon a square foot of the earth's surface there, does not weigh as much, by about 130 lbs., as that which is superincumbent upon a square foot here.

The unexplored regions environing the South Pole embrace in round numbers an area of eight millions of square miles. The quantity of atmosphere that rests upon these eight millions lacks then, according to these observations and this computation, no less than 12,943,500,000,000 tons in weight, of being as much as usually rests upon an area of like extent in these northern latitudes.

This is an inconceivably great mass, whether we attempt to comprehend it by its weight or its volume.

The force of gravity, if left free to act, would distribute the air in equal quantities and alike about both poles, and make the barometric pressure nearly the same for all latitudes. There must, therefore, be some force exerted upon the air, or in the air of these unknown Austral regions, which counteracts gravity to that enormous extent, and prevents such equal distribution.

What the nature of this force may be is matter of conjecture, but we think it may surely be traced to heat. "What!" I almost hear you say, "heat enough in perpetual development about the South Pole to exert a ceaseless lifting force of 130 lbs. upon every square foot of surface within an area of 8,000,000 square miles?"

Be not startled; but freeing your mind from all bias, give me, I pray you, your attention while I endeavour to show that in this theory of a constant play of heat about the South Pole there is nothing either very startling or paradoxical.

Under the equatorial cloud ring, the mean barometric pressure is 20 lbs. less to the square foot than it is in the calm belt of Cancer. This fact is familiar to seamen, and well known to meteorologists. To this diminished pressure we owe the trade-winds, as Captain Sir James Ross and others have already remarked. More than this: in the centre of the cyclone the atmosphere is so attenuated, that its pressure is sometimes diminished below the mean pressure of the place by more than 200 lbs. to the square foot.

To what, if not chiefly to heat, shall we attribute this? But whence comes the heat at such times and places? Clearly, it is not direct heat impressed upon the air then and there by the rays of the sun.

The equatorial cloud ring overhangs a region of constant precipitation, and the low barometer in the vortex of a tornado is always attended by deluges of rain. Here then we have a condition that accompanies the place of low barometer, both in the calm belt and the vortex. During this heavy precipitation that takes place in the centre of the storm, immense volumes of heat, that is always latent in aqueous vapour, are set free among the clouds; it warms and expands and drives off the upper air. Thus, that below is made to rush in at the surface, either, as the case may be, with the constancy of the gentle trades, or the violence of the hurricane, according to the extent and manner of the rarefaction. Moreover, the vapour before it is formed into rain, being lighter than the air, also assists to drive it away, so that the barometer would stand higher under air that is dry, than under air that is damp, even were there no vapour condensed. Now then survey, if you please, on a chart or globe, the Austral regions on the solar side of 40° S., and tell me what do you see? Why, all the way around, between that parallel and the Antarctic Circle, you see an almost uninterrupted expanse of water. Indeed, with the exception of Patagonia, and a few comparatively small islands here and there and far between, we have nothing but one continuous evaporating surface. Throughout this entire expanse the prevailing winds are from the northward and westward. These are the "brave west winds" of the southern hemisphere. They are strong winds; they suck up from the sea moisture as they go; they waft immense clouds of it over into the unexplored regions that encircle the pole. This vapour is to the winds what fuel is to the steamer; the latent heat contained in it being developed, is at once the source of power in the air, and the means of locomotion for the blast. Thus loaded, these winds impinge, with their vapour and its latent heat, upon the icy barrier or upon the mountains there, where it is condensed, and its heat set free to become sensible heat. Thus the severity of the Antarctic winter is mitigated by heat that is rendered latent by the processes of evaporation in warm latitudes, and conveyed to the south by invisible couriers through the air. This heat being thus conveyed and liberated, warms and expands, and causes the polar air to ascend, as the same kind of heat causes the air in the centre of the cyclone to ascend and flow off, creating, like a huge stack to some immense furnace, a draught and inrush of air on the surface, from the distance of miles around. This draught into the Antarctic unknown, extends from the South Pole all around to the distance of 3000 miles towards the Equator.

About the North Pole we have no such expanse of water, no such wafting of vapour, no such low barometer, no such inrush of "brave west winds," and consequently no such mildness of climate.

Behold all the rivers of Arctic America, Europe, and Asia! The rains that feed them are but occasional and gentle showers in comparison with those for which the great expanse of southern waters affords the vapours; and yet, in the condensation of the vapour for the rains to feed these rivers, heat enough is set free in the clouds to raise from the freezing- to the boiling-point, and as fast as it flows, more than five times the volume of water that the said rivers discharge into the sea.

But how the latent heat of vapour when set free in the clouds may reach down and warm the earth, may perhaps be understood by referring to a meteorological necessity, which requires, *when the windward side of the mountain is rainy, the lee side to be warm.*

To illustrate this, let us suppose a gossamer sack, capable of being hermetically sealed; that it is impervious to heat, and elastic as the air itself; that with the barometer at 30 in., the temperature at 60°, and the dew-point the same, this sack be filled with air; that then it be attached to a balloon and sent up in the sky, to a height where the barometric pressure is only 15 in., and where the temperature of the air in the sack, by reason of this diminished pressure, and by virtue of the expansion of the air within and its consequent cooling, is reduced to zero. By this process, the vapour with which the air was loaded when it was admitted into the sack has, let it be assumed, been condensed, and consequently its latent heat set free in the sack.

Suppose now the sack be hauled down to the surface again, where the barometric pressure is 30 in., as before, and what have we? The sack is reduced to its former dimensions you will perceive, but instead of damp air we now have it filled with dry; moreover, there is at the bottom a measure of water—the condensed vapour. This dry air, instead of being at the temperature of 60°, has a temperature of 60° *plus* the quantity of heat that it would require to raise $5\frac{1}{2}$ such measures of water from the freezing- to the boiling-point. In other words, we have but illustrated a natural process that is continually going on and well understood, by which heat is bottled away in vapours, wafted by the winds from clime to clime, liberated, and finally, in the processes of vertical circulation, drawn down from the crystal reservoirs of the sky to temper and warm the surface of the earth.

When the vapour-laden west winds of the South Pacific strike against the windward side of the Patagonian Andes, are they not by nature herself subjected to a process precisely analogous to that of vapour-laden air in the hypothetical sack? Striking against the western slopes of the mountain, they are forced up to the top of the snow-capped range. Here condensation of vapour and the liberation of its latent heat take place; and though the cold be extreme at the top, in consequence of the state of aërial rarefaction there, yet the winds having received the heat liberated from their vapours, are, before it can be dispersed by radiation, forced over from the eastern slopes. Here descending into the valleys, and being again compressed by the full weight of the barometric column, the heat they have received is fully developed, and they are felt as warm winds, just as the air brought down in the sack was warm. The mild climate of Eastern Patagonia and the Falkland Islands is due to caloric thus conveyed, developed and dispersed.

To appreciate the amount of heat thus conveyed and distributed, let us compare the climate of Eastern Patagonia, between the parallels of 50° and 52° south, with the climate of Labrador, between the corresponding parallels north. Those who would judge of climate, as philosophers formerly did, viz. according to latitude, would say these two climates are duplicates of each other, for the two places are equidistant from the Equator, and in both countries west winds are the prevailing winds; they both also have a continent to windward, an ocean to leeward; flowing in from each and along their eastern shores, there is likewise an ice-bearing current. But what do modern researches show? They show that the winter climate of Labrador is ice-bound, bitter in the extreme, and incapable of affording vegetable subsistence for man and beast; that that of Patagonia in the corresponding latitude south is, on the other hand, quite open and mild, affording grasses for cattle all the winter through.

How is this? The two places, though on opposite sides of the Equator, are, let it be repeated, equidistant from it. They are on the same side of the continent, and the same shore of the ocean; then why should there be such a difference in their winter climate? Investigation answers, simply because of the difference in the quantity of moisture which the prevailing winds, which also are the same, bring near the two places for condensation. The west winds of Labrador, as they cross the Rocky

Mountains, are robbed of their moisture which they sucked up from the Pacific, and the heat set free in the process is dispersed by condensation and radiation long before the winds can convey it to Labrador. But in East Patagonia and the Falkland Islands, the air, charged with heat received from the heavy precipitation on the top of the Andes, is brought directly thence to the plains below, and before it has had time to grow cold.

The influences to which is due this great difference between the winter climate of Labrador and of Patagonia are even more marked in their effect upon the Arctic as contrasted with the Antarctic winter.

The Patagonian-like climate of the south is repeated in the north along the eastern base of the Rocky Mountains. On their western slopes, the vapours from the Pacific are condensed into rains for the Columbia and Frazer and other rivers. The heat that is there liberated in this process is sufficient to raise from the freezing- to the boiling-point all the water that could be supplied by a quintuple set of such rivers. This heat makes green pastures on the eastern slopes of the Rocky Mountains, where the buffalo, in herds of countless numbers, finds winter pasturage. Now, along the same parallels in Labrador it is simply impossible, on account of the extreme cold, for a buffalo or any other graminivorous animal to find other winter subsistence than mosses and lichens.

A still more striking instance of the climatological influence of continental, in comparison with oceanic winds upon countries in high latitudes, is afforded by Ireland and Labrador, between the parallels of 51° and 53° N. In both countries the prevailing winds are also from the west. But those in Ireland come laden from open sea with vapours, which, being condensed upon the hill-sides, liberate their heat and dispense warmth, which gives to that "Gem of the Ocean" its name of Emerald. The same difference of climate, owing to wet winds from the sea and dry winds from the land prevailing at places having the same latitude, is repeated upon the N.W. coast of America and the N.E. coast of Asia.

The unexplored regions of the South Pole are surrounded by open water; those of the North for the most part by land. The winds that blow into the Frozen Ocean of the North are continental winds; the climate there, like that of Labrador and Siberia, is proportionably severe.

The winds that blow in upon the unknown South being therefore oceanic winds, there is probably as much difference of winter climate between the two polar regions as there is between the winters of Labrador and of Ireland, or the Falkland Islands.

Now then, with these facts and suggestions impressed upon our mind, let us once more turn to the unknown regions of the Antarctic. They are fringed with icy barriers abutting, as far as exploration has reached, up against lofty peaks and mountain ranges. The air that strikes upon their northern face is heavily laden with vapour. Traversing that immense waste of waters, it impinges upon those slopes completely saturated with moisture. Here all that moisture is wrung out of it. The heat that is liberated by the process is sufficient to attenuate the air in the remarkable manner indicated by the barometer, exhibited by observations, and repeated in the Tables and Plates of this Monograph. If we would know how heavy this precipitation is, how high the mountains, steep the declivities, and great the development of latent heat there, let us consult the icebergs—they afford unmistakeable indications upon the subject. The Antarctic icebergs are of fresh, not of salt water. Towering 200 or 300 feet above the sea and reaching 600 or 800 feet below*, as many of them do, they literally dot with their huge masses an extent of ocean that embraces no less than 17,000,000 square miles in its superficial area. As much heat as it takes to melt and convert into vapour again all these immense masses of ice, is set free on those unknown hill-sides, when the water to form them of was wrung out of the clouds.

Doubtless this vapour with its heat impresses characteristic features upon the winter climate of the South Pole; and thus we are impelled by the winds, persuaded by the barometer, nay, urged by the longings of the human heart, and encouraged by the great laws of Nature herself to venture and explore.

To sum up, the physical features of the northern hemisphere indicate that the climate of the Arctic regions is continental, for they are surrounded by land; exploration confirms it. On the contrary, those of the southern hemisphere indicate that

* Sir James Ross estimated an ice-barrier that he saw to be a thousand feet thick.

the climate of the Antarctic is marine, for those regions are surrounded by water. No explorer has spent a winter there to prove it, but all the known facts and circumstances seem to confirm it. An example or two will make it plain *that it must be so.* Labrador is the type of a continental climate; Ireland of a marine in the same latitude. As the summer of Ireland is cooler than that of Labrador, so may the Antarctic summer climate be cooler than the Arctic.

The average mid-winter temperature of Iceland is but 13° colder than its average July temperature; whereas the difference between the mean winter and summer temperature of Fort Simpson is 70°. But this Fort, great as is this contrast of climate, is situated within the sweep of the S.W. winds from the N. Pacific, and therefore its climate is only semi-continental. Nevertheless its summer temperature is 15° higher than that of Iceland. Now these two places are in about the same latitude north, but with this striking difference—one is surrounded by water as the Antarctic is, the other by land, as the Arctic.

The islands of the sea, and the interior of continents throughout the world in high latitudes, abound in such climatic contrasts.

The difference between the mean winter and summer temperature of the marine climates of the south is probably, and for obvious reasons, not so great as it is in corresponding latitudes north. The lowest point reached by a self-registering thermometer, not for a season or a month, but in the coldest day during a period of several years at the South Shetland Islands, in 63° S., was 5° Fahr. At Yakoutsk, on the other hand, which in Asia is about as far from the North as the South Shetlands are from the South Pole, and in a truly continental climate, the thermometer goes down in winter to 70° Fahr.*, while for July its mean temperature is 60°†. Thus, though 10° of lat. further to the north, it receives the same amount of heat in summer that is felt at Dublin‡; one place being near to and surrounded by sea, the other far removed from open water and the influences of the copious discharge of latent heat which attends the heavy condensation of aqueous vapour.

In winter, however, and owing to the same influences, the thermometer at Yakoutsk, annually for about two weeks, sinks full 100° below the mean winter temperature in Iceland. The difference between continental and marine climates becomes more marked, not only as we approach the Pole, but as the places are more or less contiguous to the open sea, and exposed to west winds from the ocean or dry winds from the land. Indeed, the summers of Yakoutsk are warm enough to grow vegetables, ripen fruits, and afford grass for cattle.

The climates of all the lands which have been visited in high southern latitudes are eminently marine. In marine climates the summer is cool, the winters warm; take for types the British Isles and Canada. There is not, during the Antarctic summer, warmth enough in the solar ray to call into play any vegetable forces beyond the feeble energies of mosses and lichens. There, as in Iceland and all other *marine* places, there is comparatively but little difference between the summer and winter climates. The mean difference between the average winter and average summer temperature in the Antarctic, as indicated by the South Shetland observations, is less than the change often experienced with us here between the temperature of the evening and the morning of the same day.

Cool summers, warm winters, and evenness of temperature the year round being the characteristics of marine climates, we should look for great uniformity in those of high southern latitudes. It is their extraordinarily cool summers, as reported by navigators, which have created the impression in nautical circles that the cold of the Antarctic winter is far more extreme than that of the Arctic. This was the impression made upon the mind of Cook, the bravest of the brave. He was a close observer, and there is no authority which to this day has more weight in seafaring circles, and none which requires more stubborn facts to set aside.

On the 14th of January, eighty odd years ago, that accomplished navigator discovered (it being then midsummer of the southern hemisphere) an island in lat. 54° and 55° S., which corresponds in lat. with Ireland. On the 17th he landed to take possession of it. He called it Georgia, but did not think "any one would ever be benefited by this discovery," for its "valleys lay covered with everlasting snow,"

* Erman. † Dove. The mean temperature for January is 40°.
‡ Colonel Sir Henry James, Ordnance Survey.

and "not a tree was to be seen, not a shrub even big enough to make a toothpick."

Contemplating this, to him, strange climate, he remarks, "who would have thought that an island of no greater extent than this, situated between the latitude of 54° and 55°, should, in the very height of summer, be in a manner wholly covered many fathoms deep with frozen snow?"

But pushing on still further, with that prowess and intrepidity which makes his history so romantic and himself the picturesque man of the sea, he discovered Sandwich Land, in lat. 59°–60°, when he made "bold enough to say that no man would ever venture further; that the lands to the south would never be explored, for they were doomed by nature to perpetual frigidness, never to feel the warmth of the sun's rays; whose horrible and savage aspect" he had not words to describe.

In all these speculations, however, he was mistaken, for other explorers have gone further south; and the very islands that in his *opinion* were never to benefit any one, have afforded to commerce seal-skins and oil to the value of many millions of dollars, and, with the island that he named Desolation, from its aspect, still give employment annually, or did a few years ago (Weddell), to 2000 tons of shipping and 200 or 300 seamen.

No explorer has yet tried the Antarctic winter. There is, my investigations lead me to believe, no great difference between it and the Antarctic summer; and the erroneous impression that has fastened itself on the public mind as to the extreme severity of winter about the South Pole, has no doubt its root in the low summer temperatures that prevail there.

If, in pleading the cause of Antarctic exploration, I be required to answer first the question of *cui bono?* which is so apt to be put, I reply, it is enough for me, when contemplating the vast extent of that unknown region, to know that it is a part of the surface of our planet, and to remember that *the earth was made for man*; that all knowledge is profitable; that no discoveries have conferred more honour and glory upon the age in which they were made, or been more beneficial to the world, than geographical discoveries; and that never were nations so well prepared to undertake Antarctic exploration as are those that I now solicit. The last who essayed it reached furthest; they were Billinghausen of Russia, forty years ago, Admiral d'Urville of France, Ross of England, and Wilkes of America,—all about the same time, and nearly a quarter of a century ago. But since that time the world has grown in knowledge, and man has gained wonderfully in his power for conquest in this field of research. We have now the sea-steamer, which former Arctic explorers had not; the experience acquired since their day, in polar exploration about the Arctic regions, enables us to overcome many an obstacle that loomed up before them in truly formidable proportions. The gold of Australia has built up among the antipodes of Europe one of the most extensive shipping ports in the world. By steam, it is within less than a week's sailing distance of the Antarctic Circle; and thus those unknown regions of the south, instead of being far remote, as in the time of all previous explorers they were, have, since exploration was last attempted there, been actually brought within a few days' sail of a great commercial mart, with its stores, its supplies, and resources of all kinds. The advantages and facilities for Antarctic exploration are inconceivably greater now than in the days of Cook and others. They are greatly enhanced by the joint system of national cooperation for the purpose of searching out the mysteries of the sea, now recognized and practised by all maritime nations. In this beautiful and beneficial cooperation, officers of the different nations have learned to pull and work together for a common good and a common glory. This habit would be carried to the South Pole by cooperation among the different nations concerned in sending out vessels for exploration there.

Nay, that great unexplored area lies at the very doors of one of the powers that is most renowned in this field of discovery. She too has taken a prominent part in this joint system of philosophical research, which has converted our ships of war into temples of science as well, and literally studded the sea with floating observatories. France, also renowned for the achievements won by her navy in peace as well as in war, is also, with her colonies, but a little further off; and the hardy Dutch are hard by. They, too, as well as the Portuguese, Spaniards, Russians, and Italians, have won renown in the field of maritime exploration. Their traditions now help me to plead the cause of Antarctic exploration. For them, with all the facilities with which we are now surrounded, with their accomplished officers and daring seamen who have given lustre to their flags, both in peace and in war, it would be an easy task now *to unbar the Gates of the South.* But in this, men and officers in other navies will also claim the privilege to join; and since all flags are alike interested and concerned in developing the physics of the sea, and in bringing to light its hidden things, it is but fair that all who are cooperating in this system of research should have "chance and opportunity" for the laurels that are to be gathered there.

Therefore, instead of confining my appeals upon this subject to my own or any one government, I venture respectfully to bring it to the attention of all.

The first step, I submit, should be to send a steamer down from Australia to search for one or more ports or places where the exploring vessels that are to follow may find shelter, and whence they might despatch boat- or land- or ice-parties, according to circumstances. This reconnaissance alone would occupy one season.

The next season, vessels suitably equipped for two or three years might be sent to take up their position, where at the return of summer they might be visited from Melbourne again, and arrangements made for the next season.

For many seasons this exploration should be a joint one among the nations that are most concerned in maritime pursuits. The advantages are manifold: each one of the cooperating powers, instead of equipping a squadron at its own expense, would only furnish one or two steamers; and these should not be large, nor should their cost be extravagant. Thus the expenses of a thorough Antarctic exploration, like those for carrying on the "Wind and Current Charts," may be so subdivided among the nations concerned as literally to be "almost nothing." It would also be attended by this further and great advantage—such an expedition could have several centres of exploration. The officers and men under each flag would naturally be incited by the most zealous and active emulation. They would strive so much the more earnestly not to be outdone in pushing on the glorious conquest.

Now the question is, what mode of procedure is best calculated successfully to bring this subject to the notice of the proper authorities in your country?

I leave that to you and other friends, trusting to them to invoke such means and to take such steps as, to them, the importance of the subject and the interests of the joint system of research, in which we and our flags are enlisted for the increase of knowledge among men, may seem to require.

Very truly, yours, &c.,
M. F. MAURY.

His Excellency the Lord Lyons,
Envoy Extraordinary and Minister Plenipotentiary of Great Britain, Washington.

On an Anemometer for Registering the Maximum Force and extreme Variation of the Wind. By JOHN E. MORGAN, *M.A., M.B. Oxon., M.R.C.P.*

The author described the instrument as consisting of an iron stand supporting a spindle. On the top of the spindle revolves a boss, on which rests a frame 13 inches in length by $3\frac{5}{8}$ in width. This frame is maintained in the direction of the wind by means of two vanes, facing each other at an angle, the more open end of the angle being directed towards the spindle. A small car with flanged wheels traverses the frame. To the face of the car is attached a thin metal plate 6 inches square, and to the back a catch playing freely over some rack-work. This catch permits the car to move towards the vanes, but checks its return to the spindle. The face of the car is connected with a balance contrived on a somewhat novel principle by means of a loaded wheel, and a lever with a weight at its lower end. By means of this balance the resistance to the progress of the car increases with its advance. The ratio of this increase is expressed in ounces and pounds engraved on one side of the frame. A hand projecting from the car moves over the scale on the dating index. The scale rises from $\frac{1}{4}$ of an ounce to 7 lbs. As the surface presented to the wind is 6 inches square, the pressure on the square foot will be exactly four times that indicated on the frame. The amount of variation in the direction of the wind, in a given space of time, is shown by means of two hands, which project from the spindle, and are capable of being directed to any part of a dial plate, on which the points of the compass are engraved by means of a rod, which is attached to, and revolves with the boss. To set this part of the instrument, it is merely required to bring one hand in contact with either side of the rod; the distance to which they are parted denoting the amount of variation in the wind.

This wind-gauge may prove useful in rifle practice and on numerous other occasions when it is important to be acquainted with the actual pressure of the wind.

Meteorological Observations at Huggate, Yorkshire. By the Rev. T. Rankin.

This was a continuation of meteorological tables and notes of weather and all remarkable meteorological occurrences during the year 1860–61, which the author has annually presented to the Association for upwards of twenty years.

On a Bathometer, or Instrument to indicate the Depth of the Sea on Board Ship without submerging a Line. By C. W. Siemens.

Those who are acquainted with the difficulties and expense attending the taking of deep-sea soundings by means of a weighted line, will readily perceive that an instrument capable of indicating depths upon a graduated scale without submerging any apparatus would be of great advantage as a means of extending our knowledge of ocean geography. In laying submarine telegraph cables through deep seas such an instrument would certainly be invaluable.

It occurred to Mr. Siemens that the total attractive force of the earth must be sensibly influenced by the interposition of a comparatively light substance, such as sea-water, between the vessel and the solid portion of the earth below. This he demonstrated geometrically as follows:—

Assuming the earth to be a perfect sphere of uniform density, two lines are drawn from a point on the surface, so as to intersect the circumference at the semicircles. A line is then drawn through the two points of intersection, which passes through the earth's centre, and a second line parallel to it, touching the circle at its lowest point. It was next demonstrated that in dividing the solid cone represented by these lines into a number of slices of equal thickness, in a direction perpendicular to its axis, each slice would exercise the same amount of attractive force upon a body at the apex of the cone, the reason being that the mass of each slice increases in the proportion of the square of its distance from the apex, and the attractive force diminishes in the same ratio. It was thus demonstrated that the true centre of gravity of the earth, in reference to an attracted body on its surface, does not reside in its geometrical centre, but in a variable point between the centre and the attracted body. In dividing the sphere itself into slices of equal thickness, a mathematical expression was obtained representing the attractive force of any of these slices; and in integrating this expression for a series of slices commencing from the point of attraction, a formula was arrived at, showing that for moderate depths the attraction of the earth may be represented by a very obtuse cone with two-thirds of the earth's radius for its height If sea-water were of no weight, the total attraction of the earth would be diminished upon its surface in the proportion of the depth to two-thirds of the earth's radius; but considering that sea-water has about one-third the weight (bulk for bulk) of the generality of rock, the actual diminution of gravitation was shown to take place in the proportion of the depth to the radius of the earth.

Accordingly 1000 fathoms of depth would produce a diminution by $\frac{1}{3200}$th part of the total gravitation—a difference so small that it appears at first sight impossible to construct an instrument capable of indicating it with sufficient accuracy.

The second part of the paper described the instrument designed for this purpose, which consists of a tube containing mercury, diluted spirits of wine, and coloured juniper oil. The mercury column, about 30 inches high, ascends in a tube from the bottom of a large bulb containing imprisoned air, and terminates in the middle of a second bulb. The remainder of the second bulb is filled with the diluted spirits, which reach upward into a narrow tube provided with a scale. Upon this rests a column of the coloured oil, which terminates in a third bulb,—the remaining space being vacuous, or nearly so. This gauge is enclosed in a glass tube filled with distilled water, which in its turn is surrounded with ice contained in an outer casing. The latter is suspended by a universal joint. The air in the lower bulb being maintained in this way at a perfectly uniform temperature, will oppose a uniform elastic force against the column of mercury, which latter, being removed from all atmospheric influences, fairly represents the gravitation of the earth.

In moving this instrument from shallow water upon a sea of 1000 fathoms depth, the mercury column would rise $\frac{1}{3200}$th part of its length in the second bulb; but before any sensible alteration has taken place in the mercury level, the upper surface of the spirits of wine terminating in the narrow tube will have risen sufficiently to restore the balance of pressure, and the spirits being twenty times lighter than mercury, the scale of observation will be increased twentyfold. But the spirit column, in rising, displaces oil of very nearly the same specific gravity, which causes another increase of scale at least twentyfold. By these means a scale of 3 inches per 1000 fathoms of depth is obtained.

An instrument of this description was tried, by permission of the Admiralty, and although it was still imperfect in some respects, its indications agreed generally within 10 per cent. with the results of actual soundings. In the course of the interesting discussion which ensued, Professor Tyndall suggested that the instrument would be equally applicable for measuring heights, and he proposed to try it with Mr. Siemens on the Cumberland Hills at some future time.

On a New Minimum Mercurial Thermometer proposed by Mr. Casella. *By* Balfour Stewart, *A.M.*

Branching off from the side of the stem of this instrument and connected with the capillary bore, we have a chamber the diameter of which is much wider than the capillary bore. This chamber is abruptly attached at its extremity to another chamber of smaller bore than itself, but still wider than the capillary tube.

To set this instrument, incline it slightly until the mercury in the side chamber comes to the abrupt termination between the two chambers. The mercury in the capillary tube will now denote the true temperature. Let this be 60°. If the temperature rise above 60°, the rise will take place in the side tube, and if it then begin to fall, the fall will also take place in the side tube until it reaches 60°; but below that the fall will take place in the capillary tube, as there is a disinclination of the mercury to recede from the abrupt termination between the two chambers towards the capillary tube. The instrument thus acts as a minimum thermometer.

On British Rain-fall. By G. J. Symons.

The author directed attention to the very contrary statements current on the question—Is there any secular variation in the amount of British rain-fall? After quoting several of the most important opinions, he stated that, in the hope of finally settling the question, he had commenced collecting all known rain-registers, and had already tabulated more than 6000 years' observations. He proceeded to invite criticism on the mode of discussion which he intended to adopt, and also on a proposed method of delineation,—the rain-fall in 1860, at 241 stations in Great Britain, being laid down on a large map as a specimen.

On some Signs of Changes of the Weather. By the Rev. W. Walton, *M.A., F.R.S., &c.*

The author combated nearly all the commonly known rules by which changes of the weather have been anticipated, and gave a few rules which he believed might be depended upon, chiefly derived from the barometer—especially if the *exceptions* to the general rules, which he clearly explained, were understood and attended to as they ought to be.

CHEMISTRY.

Address by W. A. Miller, *M.D., F.R.S. &c., Professor of Chemistry, King's College, London.*

In opening the proceedings, the President said that in the home of Dalton, in the focus of applied chemistry, very few words would be necessary. They could not but remember that, on the last occasion when the Meeting of the British Association was held in Manchester, that illustrious philosopher was still amongst them; and he trusted that the same spirit which actuated Dalton still remained in Manchester to enlighten his native county. Without saying more by way of introduction, he would call their attention to one or two points of progress during the past year. In calling attention to these subjects, he must necessarily refer to debatable ground in science,—but it was in debatable land that progress was necessarily made. He would only touch upon two or three practical applications of chemistry, and two or three theoretical ideas which had been propounded since they last met. The Professor then alluded to the new methods of preparing oxygen and hydrogen, proposed by Deville, which admit of application on such a scale as to allow of the generation of oxygen for manufacturing purposes, and the employment of the oxyhydrogen blast as a source of heat in metallurgical operations. The novelty in the preparation of oxygen consists in decomposing the vapour of sulphuric acid, and, by a further process, storing up the oxygen in gas-holders. The preparation of hydrogen required more care. The metallurgy of platinum had already experienced a remarkable modification, owing to the application of the intense but manageable source of heat obtained by the combustion of these gases. In connexion with oxygen might be mentioned a singular circumstance regarding ozone, which, according to the observation of Schrötter, had been found in a peculiar species of fluor spar, from Wolsendorf, which, when rubbed or broken, emitted a peculiar odour of ozone. The active chemist Deville, in following his researches, had discovered a variety of means of obtaining artificially, crystallized minerals of great regularity and beauty. The methods adopted were chiefly by heating the amorphous substances in a slow current of some gas, such as hydrochloric acid, which was not an unfrequent natural product in volcanic districts. No discovery, however, had made a greater impression upon the popular mind than that of the remarkable alkaline metals cæsium and rubidium by Kirchhoff and Bunsen. These eminent men, in investigating the appearances presented by flames coloured by various metallic salts when analysed by the prism, were led, from the appearance of certain bright lines in the spectra, produced whilst they were examining a saline residuum from the waters of the Dürkheim spring, to infer the existence of a substance hitherto unknown. It was found that cæsium was present in such minute quantity, that a ton of that water, which was the most abundant source of cæsium yet known, contained only 3 grains of its chloride. Taking into account the minuteness of the quantity, and its striking resemblance to potassium, it was not too much to say that the discovery of cæsium would have been impossible by any other known method than that which was actually employed. The other metal, rubidium, was somewhat more plentiful; but rubidium also so closely resembled potash that it would not have been discovered but for the peculiarity of its spectrum. Referring to the revision of the atomic weights of sulphur, silver, nitrogen, potassium, sodium, and lead, by Stas, Professor Miller said that chemist had come to the conclusion that it was not proved that the elementary bodies were multiples of the unit of hydrogen, and, in opposition to the opinion of Dumas, he had pronounced the law of Prout as imaginary. Every chemist would read with interest the paper by Graham upon the application of liquid diffusion to analysis. The remarkable conclusion to which the author arrived was, that the process of diffusion separated all substances into one or other of two classes, which he distinguished as crystalloids and colloids. The rapid improvement in the method of analysis, though not admitting on that occasion of detailed mention, must not be overlooked. A variety of bodies, formerly supposed to be of rare occurrence, were now found in minute quantities, unexpectedly, but widely diffused. The discovery of these small quantities was by no means unimportant, for they might aid in solving problems of great interest. Glancing only for a moment at the important practical subject of the formation of steel, Professor Miller referred to the activity employed in the pursuit of the organic department of chemical science; remarking upon two lines of research as important from their theoretical bearings, namely the investigation of polyatomic compounds, and the process of oxidation and of reduction, applied by various chemists, and by Kolbe in particular, to the investigation of the organic acids. The labours of Hofmann upon the polyatomic bases showed completely the principle upon which these bodies might be formed, and he had been enabled to group an unlimited number of atoms of ammonia into one compound molecule. Great progress had also been made in our knowledge of the relations of the organic acids.

On the Constitution of Paranaphthaline or Anthracene, and some of its Decomposition Products. By Professor ANDERSON, *F.R.S.E.*

The author, after referring to the previous investigations of Laurent and Dumas, which indicated the isomerism of naphthaline and anthracene, detailed the results of his own researches, which have established for the latter substance the formula $C_{28}\,H_{10}$. Anthracene, when treated with nitric acid, undergoes a decomposition entirely different from that of naphthaline under similar circumstances, and yields an oxidized compound, oxanthracene, $C_{28}\,H_8\,O_4$, which is volatile without decomposition, and crystallizes in fine needles of a pale buff colour. Bromine gives $C_{28}\,H_{10}\,Br_6$ in small hard crystals apparently rhombohedral, which when digested with alcoholic potash give $C_{28}\,H_8\,Br_4$ in fine sulphur-yellow crystals. Chlorine gives $C_{28}\,H_{10}\,Cl_2$, and this with alkalies yields $C_{28}\,H_9\,Cl$.

These and other details contained in the paper show that anthracene is not isomeric with naphthaline, but they connect it with the benzoyl series, and more especially with stilbene, from which it differs by H_2; while oxanthracene and benzil are similarly related to one another, as shown by the following comparison of their formulæ:—

Anthracene	$C_{23}\,H_{10}$	Stilbene	$C_{28}\,H_{12}$
Oxanthracene	$C_{28}\,H_8\,O_4$	Benzil	$C_{28}\,H_{10}\,O_4$

The author proposes to prosecute the investigation of these relations.

On the Effect of Great Pressures combined with Cold on the Six Non-condensable Gases. By Professor ANDREWS, *M.D., F.R.S.*

In this communication the author gave an account of some results already obtained in a research with which he is still occupied on the changes of physical state which occur when the non-condensable gases are exposed to the combined action of great pressures and low temperatures. The gases when compressed were always obtained in the capillary end of thick glass tubes, so that any change they might undergo could be observed. In his earlier experiments the author employed the elastic force of the gases evolved in the electrolysis of water as the compressing agent, and in this way he actually succeeded in reducing oxygen gas to $\frac{1}{300}$th of its volume at the ordinary pressure of the atmosphere. He afterwards succeeded in effecting the same object by mechanical means, and exhibited to the Section an apparatus by means of which he had been able to apply pressures, which were only limited by the capability of the capillary glass tubes to resist them; and while thus compressed the gases were exposed to the cold attained by the carbonic acid and ether bath. Atmospheric air was compressed by pressure alone to $\frac{1}{371}$ of its original volume, and by the united action of pressure and a cold of $-106°$ F. to $\frac{1}{675}$th, in which state its density was little inferior to that of water. Oxygen gas was reduced by pressure to $\frac{1}{324}$th of its volume, and by pressure and cold to $\frac{1}{554}$th; hydrogen by the united action of cold and pressure to $\frac{1}{500}$th; carbonic oxide by pressure to $\frac{1}{278}$th, by pressure and cold to $\frac{1}{278}$th; nitric oxide by pressure to $\frac{1}{310}$th, by pressure and a cold of $-160°$ F. to $\frac{1}{680}$th. None of the gases exhibited any appearance of liquefaction even in these high states of condensation. The amount of contraction was nearly proportional to the force employed, till the gases were reduced to from about $\frac{1}{300}$th to $\frac{1}{350}$th of their volume; but, beyond that point, they underwent little further diminution of volume from increase of pressure. Hydrogen and carbonic oxide appear to resist the action of pressure better than oxygen or nitric oxide.

On the Chemical Composition of some Woods employed in the Navy. *By* Dr. Crace Calvert, *F.R.S.*

The author thought that it might prove interesting to ship-builders if he were to investigate the chemical composition of the various woods employed in the Navy; especially when this important adjunct of England's wealth is undergoing such extensive modifications, and when it is of such paramount importance to know which is the best wood to be used in the construction of the new iron-plated frigates. He had examined ten different woods, and the superiority of some foreign woods over English oak could not be too strongly expressed. If English oak has hitherto stood so high, it must have been owing to our ignorance of the valuable properties of some of the woods grown in tropical climates, in which the soluble and highly decomposable tannin of oak is replaced in some instances by resins, and in others by substances similar to caoutchouc. This is the case with Moulmein teak, Santa Maria, Moira wood, and Honduras mahogany, which gives to them a great advantage over oak for iron ship-building. Thus he has found that in the same time, and under similar circumstances, oak will attack iron twice and three times as rapidly as the woods above-mentioned. He has also remarked that if cubes of the same dimensions of the various kinds of wood remain in contact with water for five months, they lose respectively the following per-centages of their substance:—Unseasoned oak, 24; seasoned oak, 12; African teak, $3\frac{1}{2}$; Moira wood, 4; Honduras, 3; Santa Maria, 1·6; Greenheart, 5·6; Moulmein teak, 1·7. The facility of mildewing or decaying is as follows:—Unseasoned oak, rapid; seasoned oak, much less; African teak and Honduras mahogany, limited; Moira wood, Santa Maria, and Moulmein teak, none. For further details Mr. Crace Calvert would avail himself of an early opportunity of publishing a complete paper; but there was one point which he deemed it his duty to mention at once. During his researches he had found a great difference between oak felled in summer and that felled in winter, viz. that the oak felled in winter was rich in tannin, while the oak felled in summer contained little or no tannin, but a large quantity of gallic acid; and on examining some specimens of wood from unsound gun-boats furnished to him by some of Her Majesty's Officials, he found that the chemical composition of the wood of the sound gun-boat was identical with that of well-seasoned oak, while the composition of the wood of the unsound gun-boat was identical with that of unseasoned summer-felled oak.

On the Chemical Composition of Steel. *By* Dr. Crace Calvert, *F.R.S.*

The author entered into some detail respecting the interesting discussion which has lately taken place before the French Academy of Science, between MM. Fremy and Caron, on the chemical composition of steel, the former contending that nitrogen is essential to the conversion of iron into steel, the latter that carbon alone is sufficient to effect that object. But an observation that Mr. Crace Calvert has made, tends to show that the molecular condition of steel has a great deal to do with the nature of its chemical composition; for if a piece of soft steel be divided into two portions, and one of these is hardened or highly tempered, the slow action of acetic acid proves to be quite different; and whilst soft steel is scarcely acted upon by weak acetic acid, hard steel is rapidly dissolved. Further, the soft steel leaves a homogeneous grey carburet of iron, similar in its texture to the graphitoid compound lately described by him (Mr. Calvert), whilst that of tempered steel is black, possesses no cohesion, and has the appearance of pure carbon.

On the Evolution of Ammonia from Volcanos. *By* Professor Daubeny, *M.D., F.R.S.*

This phenomenon had been ascribed by Bischof to the decomposition of bituminous matters by volcanic heat; by Bunsen to the lava flowing over herbage, and disengaging its nitrogen, which exhibited itself in the form of ammonia; and on former occasions, by the author of this paper, to the direct union of hydrogen and nitrogen in the interior of the earth under an enormous pressure. Now, however, that Wöhler has shown the affinity which subsists between nitrogen and certain of the metals and simple combustibles, some of which, as titanium or boron, combine with it directly with such avidity that the union is attended with combustion;

and that he has also proved the nitrides formed to be decomposed by the hydrated alkalies, ammonia being thereby generated,—it has occurred to the author that a more probable explanation of the occurrence of ammonia in volcanos might be afforded by supposing such combinations to take place in the interior of the earth, and there to be subsequently decomposed by the alkalies which are usually present wherever volcanic action is taking place. In confirmation of this view, he appealed to a late observation made by Signor Guiscardi, a distinguished naturalist at Naples, namely, that metallic titanium was found to be evolved from the crater of Vesuvius during a late eruption.

On a particular Decomposition of Ancient Glass. By H. DEANE.

The author's object was to show, first, that an incrustation observed within a glass ampulla from the ancient Christian catacombs of Rome was not organic matter, as had been supposed; and secondly, that it was the result of a decomposition of the glass itself, probably originally coloured with peroxide of iron. This in the course of time had separated, like the other ingredients of the glass, and found its way to the surface in a spheroidal and arborescent form, similar to what may be observed in moss agates. That it was not a mere extraneous deposit was obvious from the fact of its being chiefly in the substance of the glass itself, and nearly equally distributed on both inner and outer surfaces. He had observed precisely the same condition in some ancient glass from Nineveh.

On Morin, and the non-existence of Morotannic acid. By Dr. DELFFS.

M. Wagner published in the year 1850 an investigation on the wood of *Morus tinctoria*, and stated that this wood contains two peculiar and isomeric matters, *morin* and *morotannic acid*, the latter of which differs from all other tannic substances by being able to crystallize. Since that time no other chemist has discussed the same subject. The author thought, therefore, a repeated investigation on morin and morotannic acid would not be superfluous, and found that morotannic acid is only morin in an impure state, and that an often-iterated crystallization suffices to convert it into a white substance possessing all the properties of pure morin. The composition of morin corresponds to the formula $C^{14} H^5 O^6 + 2HO$. M. Wagner gives the formula $C^{18} H^8 O^{10}$. Morin most resembles catechin: it gives, when heated above its melting-point, pyrocatechic acid; the colour produced in the solution of catechin by chloride of iron is nearly identical with that which is caused by the same test in the solution of impure morin; and a comparison of the composition of catechin, which Dr. Delffs found seventeen years ago (Jahrbuch für praktische Pharmacie, vol. xii. p. 162), and that of morin will show that the difference between both is not very great. The author tried, therefore, to convert catechin by repeated crystallization into morin, but without result, and he is quite convinced that these two substances are not identical.

On Piperic and Hydropiperic Acids. By G. C. FOSTER, *B.A., F.C.S.*

The analysis of piperic acid and of the piperates of potassium and barium led to the formula $C^{12} H^{10} O^4$ * for the acid, and to the formula $C^{12} H^9 MO^4$ for the salts; thus confirming Strecker's formulæ †. A warm aqueous solution of piperate of potassium is converted, by treatment with sodium-amalgam, into hydropiperate of potassium. Hydropiperic acid melts to a transparent oil under hot water, and dissolves in all proportions in alcohol: it contains $C^{12} H^{12} O^4$. The following hydropiperates were analysed:—

Hydropiperate of ammonium	$C^{12} H^{11} (NH^4) O^4$.
Acid hydropiperate of potassium..	$\left.\begin{matrix} C^{12} H^{12} O^4 \\ C^{12} H^{11} KO^4 \end{matrix}\right\}$.
Hydropiperate of calcium.........	$C^{12} H^{11} CaO^4$ (at 100°).
Hydropiperate of barium..........	$C^{12} H^{11} BaO^4$.
Hydropiperate of silver	$C^{12} H^{11} AgO^4$.

* C=12, H=1, O=16.

† Ann. Chem. Pharm. cv. 317.

On the Composition and Valuation of Superphosphates. *By* Professor GALLOWAY.

On an Aluminous Mineral from the Upper Chalk near Brighton. *By* Dr. J. H. GLADSTONE *and* Mr. G. GLADSTONE.

In an old chalk-pit at Hove there are many faults, and some of these are filled up with a white soft mineral that runs along the broken layers of flint and imbeds the fragments. It appears in agglomerated masses, which easily fall to powder, and are porous. Sp. gr. 1·99. One piece that was analysed proved to be the hydrated disilicate of alumina, that has received the name of Collyrite, with no other impurity than one per cent. of carbonate of lime. Another piece contained 13 per cent. of carbonate of lime, and 5 per cent. additional of carbonic acid, which was supposed to be combined with alumina. As the silicic acid was proportionally smaller in quantity, this piece was viewed as collyrite in which about half the silicic acid had been replaced by carbonic acid.

On the Emission and Absorption of Rays of Light by certain Gases. *By* Dr. J. H. GLADSTONE, *F.R.S.*

This communication arose out of an attempt to determine what constituents of the air give rise to the "atmospheric lines" of the solar spectrum, of which a map had been exhibited by the author at the Leeds Meeting of the Association, and which had been since published in a more complete form by Sir David Brewster and himself. A comparison of the bright rays emitted by nitrogen, oxygen, hydrogen, carbonic acid, and water, when strongly heated, had shown that they do not coincide with the absorption-bands of the atmosphere. It is possible that the three bright lines of the hydrogen spectrum, as given by Angström and Plücker, may be in the same position as C1, F, and ρ of the atmospheric spectrum. Yet the author inclined to the belief that these absorption-bands are due to two or more different constituents in varying proportions, more abundant in some places than in others, and probably in very minute quantities.

The following facts were mentioned among others:—The flame of carbonic oxide burning in air gave a continuous spectrum from about C to about k, where it ceased rather abruptly: it was without either bright or dark lines. The alcohol flame shows four bands—the first faint in the yellow, nearly midway between D and E; the second brighter, green, just beyond b, with the refractive index 1·6254 for glass, which gives as the refractive index of b 1·6249; the third faint and blue, about half-way between F and G; the fourth a more luminous double line, violet, with the refractive index 1·6413, that of the line G being 1·6404. The oxyhydrogen flame gave a continuous spectrum principally green and blue, extending to about G 33, with no lines corresponding to the hydrogen lines of Angström and Plücker. The lightning flash gave a continuous spectrum, showing all the colours from red to violet, with doubtful indications of more luminous bands. That there is no necessary correspondence between the lines of absorption of a gas at the ordinary temperature, and the rays emitted by it at a high temperature, is strikingly proved by iodine, where the absorption-bands delineated by Professor Miller, the groups of green and blue bands produced when the vapour is introduced into a Bunsen's flame, and the lines of the rarefied gas as observed by Plücker, are perfectly different. By the prismatic analysis of solar light, the absence of the coloured gases from the air can be proved, even in very minute quantity. Thus the author observed that about $\frac{1}{100}$th of an inch of bromine vapour interposed between the eye and the object-glass of the refraction goniometer was sufficient to exhibit the absorption-bands; and from this he had reckoned that if free bromine constituted one thousand millionth part of the atmosphere, it would betray its presence in the solar spectrum when the sun was on the horizon; but there is no such indication. This, however, rests on the unproved assumption that a gas almost infinitely diffused along a given line will produce the same absorbent effect as if its particles were all close together at some point along that line.

On the History of the Alkali Manufacture. By W. Gossage.

The author believed that the manufacture of soda in Great Britain, by the special decomposition of common salt, had its commencement in Lancashire; at any rate, its largest development had taken place in this county. Previously to the establishment of the French republic, in 1793, soda was obtained almost entirely from the ashes of marine plants growing at Alicante in Spain, Sicily, Teneriffe, and on the coast of Great Britain. Large quantities of potash were also imported from Russia and America, but now soda was exported to those countries which formerly sent us potash. The importation of alkali into France being stopped by the French revolution, a committee was appointed by the French convention to discover means of supplying the article from France itself. The process suggested by Le Blanc was approved of; but it was erroneous to suppose that his process was not invented before the committee was appointed. Having given an account of Le Blanc's invention, Mr. Gossage said that it was very complete, and was the same as now used in both England and France. This invention had done more to promote civilization than any other chemical manufacture. The poor inventor, however, met with the too common reward of talent, and after great privations died in an asylum for paupers. Sundry alkali works were erected in France; but the process was not introduced into England until some years afterwards. In 1787 Messrs. Gordon, Barron, and Co., of Aberdeen, applied chlorine, then recently discovered, to the process of bleaching. A large establishment was in the following year established at Bolton. At first chlorine was used in the state of solution in water, but the inconvenience of using it in that manner was overcome by the addition of potash to the water. The next step was to substitute lime for potash, producing solution of chloride of lime. This was the invention of Mr. Charles Tennant, of St. Rollox, who afterwards manufactured chloride of lime in the state of powder. This manufacture was carried out to a great extent. A great obstruction to the manufacture, however, was the high excise-duty on salt, which operated most injuriously. When Mr. Tennant's patent for manufacturing bleaching powder expired, other parties began the same manufacture. Attention was directed to the utilization of the mixed sulphate of soda and sulphate of manganese resulting from this manufacture, and carbonate of soda, in crystals, was gradually introduced into the market. During the same period Mr. Losh was making crystals of soda, and might be considered the father of the soda trade in this country. Mr. Losh finished his education on the continent, where he learnt Le Blanc's processes. After his return, he obtained permission of Government to work a spring of weak brine discovered at Walker, on the Tyne, for the manufacture of soda. He there manufactured soda crystals; but notwithstanding these essays, 1823 might be considered the natal year of the soda trade as a special manufacture in Great Britain. In that year common salt being relieved from fiscal impost, Mr. James Muspratt commenced the manufacture of sulphate of soda at Liverpool, to be used for the manufacture of carbonate of soda. Mr. Muspratt adopted Le Blanc's processes in their entirety. He had to contend with many difficulties, but he overcame them all, and reaped a satisfactory reward. Other manufacturers also commenced to make sulphate of soda, by the special decomposition of common salt for the purpose of making soda; and it had since been found advantageous to adapt this method of working to the production of bleaching powder, by using the hydrochloric acid so obtained to generate chlorine by its action on manganese. In the early days of the soda trade no attempt was made to condense the liberated hydrochloric acid gas. The old apparatus of cylinders and Woulfe's bottles was totally inadequate for the condensing. Many plans were suggested, and amongst others he (Mr. Gossage) obtained a patent in 1836. Having demonstrated the practicability of effecting a complete condensation of hydrochloric acid, by the erection and working of a set of apparatus at the soda works with which he was then connected, he introduced the plan to the trade, and it had been subsequently adopted by every manufacturer. The principle of the invention consists in causing the acid gas to percolate through a deep bed of coke, in small lumps, contained in a high tower, at the same time that a supply of water flowed very slowly over the surface of the pieces of coke. By this means an almost unlimited extent of moistened surface was presented to the gas for effecting its absorption, and as the same fluid descended through the tower, it met with more gas and gradually became charged to saturation; whilst, at the upper portion of the tower, any gas which might otherwise escape was exposed to the absorbing power of unacidulated water. In 1838, a French house, Messrs. Taix and Co., of Marseilles, obtained a monopoly from the King of Sicily for the export of sulphur. This caused an advance in price to £14 per ton, from the previous rate of £5 per ton. It was found that in our Cornish mines and in those of Wicklow in Ireland, we possessed an inexhaustible supply of sulphur in the form of pyrites; and our practical chemists soon availed themselves of this source for the manufacture of sulphuric acid. In working with pyrites it was found that this mineral contained sulphide of copper as well as sulphide of iron, and at an early period he commenced to extract the copper from the burnt residuum by smelting. At the present time, the products obtained by the soda manufacturers were soda ash, worth £8 per ton; soda crystals, about £4 10*s.* per ton; bleaching powder, £9 per ton; bicarbonate of soda, £10 per ton; whilst the cost of raw materials, now used in Lancashire, is—sulphur, £8 per ton, for which was substituted pyrites at a cost equivalent to £5 per ton; common salt, 8*s.*; limestone, 6*s.* 8*d.*; fuel, 6*s.* per ton. Thus, with a reduction in the cost of raw materials not more than equal to 10 per cent. the public was supplied with the products of the soda manufacturer at a reduction of at least 60 per cent. As nearly as he could obtain information, there were 50 establishments in Great Britain in which soda was manufactured by Le Blanc's process, producing about 3000 tons of soda ash, 2000 tons of soda crystals, 250 tons of bicarbonate of soda, and 400 tons of bleaching powder per week. The total amount of these products might be estimated as exceeding two millions sterling, which was so much entirely added to the annual income of the country, excepting about £100,000 paid for materials obtained from other countries. He must not omit to notice the prospect of a new market for British-made soda which had been opened by the successful labours of Mr. Cobden, in negotiating the commercial treaty with the French government.

Many attempts had been made to supersede Le Blanc's process, by some more direct means of operating on salt, so as to eliminate its soda at once. Up to the present time, the result of all these attempts had been the wasteful expenditure of large sums of money. Two-fifths of the total cost for raw materials was incurred for pyrites from which to procure a supply of sulphur; and it was a well-known fact that more than nine-tenths of this sulphur was retained in the material called "alkali waste," which was thrown away by the manufacturer. Thus was presented a problem which, if it could be solved, would effect a large reduction in the cost of soda. Many chemists, both scientific and practical, had given a great amount of attention to the subject. He had been so unfortunate as to be amongst the number, as he had devoted a great proportion of his time, during a quarter of a century, and a large amount of both money and labour to this hitherto delusive subject. He commenced by demonstrating, in 1838, that one equivalent of carbonic acid would decompose one equivalent of sulphide of calcium, producing monocarbonate of lime and sulphide of hydrogen. This decomposition was contrary to the received views of scientific chemists of that day, as it was held that an excess of carbonic acid was needful to effect the perfect decomposition of sulphides. He was convinced that whenever the utilization of the sulphur in alkali waste should be effected, it would be by means of this action of carbonic acid. He demonstrated also, at the same time, that one equivalent of carbonic acid would decompose one equivalent of sulphide of sodium, producing monocarbonate of soda and sulphide of hydrogen. His present impression was that Le Blanc's processes would be modified by the omission of lime when decomposing sulphide of soda, thus producing sulphide of sodium; and that the carbonic acid evolved by this decomposition would be applied to decompose the sulphide of sodium, producing carbonate of soda, and eliminating sulphide of hydrogen, which would be absorbed by peroxide of iron, and the product used in the manufacture of sulphuric acid. He had proved the correctness of all those decompositions and actions; but the ideas had still to be worked into a practical operation.

On the Construction of Gas-Burners for Chemical Use.
By J. J. Griffin, *F.C.S.*

The author exhibited a series of gas-burners adapted to produce the different degrees of heat that are required for the usual operations of the experimental chemist.

They were all formed for burning a mixture of coal-gas and atmospheric air, so regulated as to produce great heat and no light. The construction of the burners was explained, and the methods of securing the proper results. The same burner could be made to give a single large flame for the ignition of a crucible, or a great number of small flames proper to warm a current of air to effect evaporations, &c. Jackets or furnaces were used for applying the heat produced by the burners so as to combine the greatest effect with economy in the use of gas. With one of these burners (the third in the series) five gallons of water could be readily boiled; a 5-inch clay crucible could be raised to a full red heat in less than half an hour; or 30 lbs. of lead or 20 lbs. of zinc could be kept in constant fusion. For very high temperatures a blast gas furnace is required. The burner belonging to this apparatus contains sixteen or twenty-six blowpipes which are acted on by a bellows. With this furnace, a quarter of a hundredweight of cast iron, and smaller quantities (two or three pounds) of such metals as malleable iron and nickel, can be completely fused in about an hour.

Note on the Sulphur Compound formed by the Action of Sulphuretted Hydrogen on Formiate of Lead at a High Temperature. By W. J. Hurst, *Student of Owens College, Manchester.*

In 1856, Limpricht* assigned to the above body, as the result of his sulphur determinations only, the formula $\left.\begin{matrix} C_2HO_2 \\ H \end{matrix}\right\} S_2$, and the name thioformic acid, from a supposed analogy to the thiacetic acid of Kekulé†, $\left.\begin{matrix} C_4H_3O_2 \\ H \end{matrix}\right\} S_2$. I lately undertook, at Professor Roscoe's suggestion, the following further examination of its properties and mode of formation.

(I.) When anhydrous formic acid is acted on by pentasulphide of phosphorus, as in Kekulé's experiment, sulphuretted hydrogen is continually evolved, and the distillate contains no sulphur in combination.

(II.) When the mixture is heated in closed tubes to 106° C., or (III.) to the same temperature under a pressure of three atmospheres, carbonic oxide and sulphuretted hydrogen are evolved, with similar negative results.

So (IV. and V.) when formiate of lead and pentasulphide of phosphorus are distilled together both in the dry and moist state. These facts seem to point to a decomposition of the thioformic acid, if formed, at the temperature of the experiments. Thus,

$$\left.\begin{matrix} C_2HO_2 \\ H \end{matrix}\right\} S_2 = C_2O_2 + \left.\begin{matrix} H \\ H \end{matrix}\right\} S_2.$$

I obtained Limpricht's body by his method, but in much smaller quantities than he mentions. After purification by repeated crystallizations from hot formic acid, and drying in vacuo over sulphuric acid, analyses yielded the following results:—

	Found.				Calculated for the formula $\left.\begin{matrix} C_2HO_2 \\ H \end{matrix}\right\} S_2$.
	(I.)	(II.)	(III.)	(IV.)	
C	27·93	29·25	28·21	..	19·3
H	4·70	4·83	5·23	..	3·2
S	58·11	..	56·7	55·15	51·6
O	..	..	..	..	25·9

Limpricht's numbers were—

	I.	II.	III.
C	26·1	25·7	23·4
H	5·6	4·7	6·3
S	51·2	52·5	..
O	..	..	..

I estimated the sulphur by oxidation with warm nitric acid, observing the necessary precautions; the carbon and hydrogen after Carius'‡ method; and after the

* Ann. Chem. Pharm. xcvii. 361.
† Ann. Chem. Pharm. xc. 309; and Phil. Mag. [4] vii. 518.
‡ Ann. Pharm. cxvi. 1.

combustion the water of the chloride-of-calcium tube was found to be *quite free* from sulphurous acid. Although these analyses, in the absence of a vapour-density or atomic weight determination, which the small quantity of the substance did not permit, yield no definite formula, yet they and the previous experiments show clearly that the body is not thioformic acid. It crystallizes readily in white shining needles from hot alcohol, ether, acetic or formic acids, the alcoholic solution being neutral to test-papers. The crystals melt at about 120° C., and sublime unchanged at higher temperatures, depositing in long silky needles,—are unacted on by hot or cold hydrochloric acid, solutions of carbonate or hydrate of potassium and sulphide of ammonium,—are decomposed by nitric and sulphuric acids, yielding a heavy white precipitate with nitrate of silver, but none with chloride of barium, when dry have little odour, but in solution in formic acid a strong penetrating sulphur smell.

On the Thermal Effects of Elastic Fluids. *By* Dr. Joule, *F.R.S., and* Professor W. Thomson, *F.R.S.*

In the year 1844, Mr. Joule showed that the thermal effects of compressing an elastic fluid and of allowing a compressed elastic fluid to expand, were to be explained on mechanical principles. He demonstrated by experiment that the heat evolved by the compression of an elastic fluid was proportional and equivalent to the force employed; and 2nd, that the cold occasioned by the dilatation of a gas was in consequence of heat turned into work. He also showed that if the dilatation of a gas is managed so as to give out no external work, no sensible thermal effect is produced. Professor Thomson showed that these results were probably only approximate to the truth, and would differ from it in proportion as the gas did not observe the so-called gaseous laws, and he devised the plan of experimenting, which the authors have since carried on in concert, in order to show the small but certain thermal effect of expanding elastic fluids without giving out work. The method the authors employed is to allow an elastic fluid confined at high pressure to escape through a porous plug. It is obvious that if the gas obeyed the gaseous laws accurately, no change of temperature would be occasioned by this process, for the cold of dilatation would be exactly balanced by the heat arising from the friction of the air in the plug. This is evident from the circumstance that the product of the pressure through the space would be the same on both sides of the plug. Their first experiments, on a very small scale and with a very imperfect apparatus, decisively exhibited a lowering of temperature of air on passing through the plug, thus showing a non-observance of exact gaseous law, which was with difficulty detected by Regnault by the use of a very elaborate and costly method, only applicable to certain gases under peculiar conditions.

The method they employed, though so extremely simple, required several precautions. In particular it was requisite to employ a porous plug of considerable thickness; for if a thin one was employed there was a rapid conduction of heat from the high- to the low-pressure side, and also an irregular effect arising from the action of numerous jets of air instead of a tranquil flow on the low-pressure side. Hence they found a too large cooling effect when a diaphragm of leather was used, in which case even hydrogen showed a slight cooling effect.

The phenomena of a jet of air are highly interesting. Issuing at a high velocity from a vessel in which it is confined at high pressure, its actual temperature may readily be made 200° below the zero of Fahr. But this very low temperature cannot be easily exhibited, because if a thermometer is immersed in the jet the friction of the air gives rise to heat which nearly neutralizes the cold. The temperature of one part of a jet may thus be hundreds of degrees different from that of another part. The authors have, in fact, shown that a thermometer may be so placed in a jet as to experience either cold or extreme heat. Hence the absolute necessity in their experiments of a porous plug, which will allow the air to issue in a tranquil flow without jets or rapids.

A general result they have arrived at on transmitting elastic fluids through a porous plug, is, that the thermal effect is proportional to the difference of pressures on the opposite sides.

A diminution of temperature takes place in all the gases tried except hydrogen; and this diminution or cooling effect is decreased when the temperature is raised, in such sort as to make it certain that at 300° or 400° it would vanish altogether and be followed by a heating effect, as is observed in hydrogen at low temperatures.

In different gases the cooling effect is very various. It is 5 times as great in carbonic acid as in atmospheric air at low temperatures, and 4 times as great at the boiling temperature.

A very remarkable fact which has been elicited by these experiments, is that a gas mixed with another does not exhibit the same thermal effects as it does when undiluted. In general a mixture of gases gives a smaller cooling effect than would be deduced from the cooling effects of the constituents. This has been verified in the dilutions of carbonic acid and hydrogen and in atmospheric air, of which each of the component gases has a larger cooling effect than itself.

The authors regret that they have not been able as yet to extend the experiments so as to show the point at which the cooling effect ceases and is followed by a heating effect in the different gases.

On some points in connexion with the Exhaustion of Soils.
By J. B. Lawes, *F.R.S., F.C.S., and* Dr. J. H. Gilbert, *F.R.S., F.C.S.*

The question of the exhaustion of soils was one of peculiar interest at the present time, not only on account of the great attention now paid to the waste of manuring matters by the discharge of the sewage of towns into our rivers, but also from the fact that Baron Liebig has recently urged that our soils are suffering progressive exhaustion from this cause, and predicted certain, though it may be distant, ruin to the nation, if our present modes of procedure be persevered in.

The question was one of chemical facts; and the authors had intended to treat it much more comprehensively than they were able to do on the present occasion. They proposed, by way of illustration, to bring forward one special case of progressive exhaustion, occurring in the course of their own investigations; and then to contrast the conditions of that result with those of ordinary agriculture.

They had grown wheat for eighteen years consecutively on the same land, respectively without manure, with farm-yard manure, and with different constituents of manure, and they had determined the amounts of the different mineral constituents taken off in the crop from the respective plots. Numerous Tables of the results were exhibited. The variations in the composition of the ash of both grain and straw, dependent on variations of season and consequent character of development and maturity, were first pointed out. The general result was, that, with an unfavourable season, there was a slight though appreciable decrease in the percentage of lime and potass, and increase in that of magnesia; and again, an increase in the percentage of phosphoric acid and of silica; and, especially in the case of the straw-ash, a decrease in that of sulphuric acid. Turning to the bearing of the results on the main subject of inquiry, it appeared that when ammonia-salts were used alone, year after year, on the same land, the composition of the ash, both of grain and of straw, showed an appreciable decline in the amount of phosphoric acid, and that of the straw a considerable reduction in the percentage of silica.

When ammonia-salts alone were used, the amount of mineral constituents in the crop of a given area of land was very much increased—much more so than when a liberal supply of mineral constituents alone was used. But in neither of these cases was there anything like the amount of mineral constituents obtained in the crop, that there was when the ammonia-salts and mineral manures were used together, or when farm-yard manure was employed. The greatest deficiency indicated was in the silica and the phosphoric acid, and next in order came potass and magnesia. The exhaustion here apparent was, however, not to be wondered at, when it is considered that, in these experiments in which both corn and straw were annually removed without the usual periodical return of farm-yard manure, there had been on the average annually taken from the land by the use of ammonia-salts, about twice as much phosphoric acid, about five times as much potass, and about twenty-five times as much silica, as would be removed under a system of ordinary rotation with home manuring, and selling only corn and meat; in fact, in sixteen years there had been taken from the land as much phosphoric acid as would require thirty-two years, as much potass as would require eighty-two years, and as much silica as would require 400 years of such ordinary practice to remove.

Again, the authors estimated that in the experiments of the Rev. Mr. Smith of Lois Weedon, on the growth of wheat year after year on the same land, without manure, there had been an annual extraction from each acre of land of about three and a half times as much phosphoric acid, about seven times as much potass, and about thirty-seven times as much silica, as there would be in the ordinary course of practice; yet, after some fifteen years the crops at Lois Weedon were said not to be at all failing.

The authors did not recommend such exhaustive practice as that quoted from their own, or the Rev. Mr. Smith's experiments. But the instances given showed the capabilities of certain soils; and in one case the conditions under which the point of comparative exhaustion had been reached. It was, of course, impossible to state the limits of the capability of soils generally, so infinitely varied was their composition; but it would be useful to give an illustration on this point. Reckoning the soil to be one foot deep, it was estimated that it would require, of ordinary rotation with home manuring and selling only corn and meat, about 1000 years to exhaust as much phosphoric acid, about 2000 years to exhaust as much potass, and about 6000 years to exhaust as much silica, as, according to the average results of forty-two analyses* relating to fourteen soils of very various descriptions, had been found to be soluble in dilute hydrochloric acid. Many soils had, doubtless, a composition inferior to that here supposed. In a large proportion, however, the amounts of the above constituents assumed to be soluble in dilute hydrochloric acid would probably be available for plants long before the expiration of the periods mentioned; whilst, in a large proportion, there would still be further stores eventually available within a greater or a less depth from the surface.

But the exhaustion of mineral constituents by the sale of corn and meat alone was in reality not so great, in the ordinary practice of this country, as has been assumed for the purpose of the above illustrations. Where there was no purchase of cattle-food, or of artificial or town manures, the sales of corn and meat would on the average be much less than were taken in the authors' estimates; and where such materials were purchased with any degree of judgment in the selection, there would always be much more phosphoric acid (otherwise the most easily exhausted constituent) so brought upon the land, than would be obtained from it in the increase of produce yielded; in fact, under such conditions, in many soils potass was more likely to become deficient. Again, by no means the whole of the mineral constituents sent from the farm in the form of corn and meat will reach the sewers of our towns, and thence our rivers; a not inconsiderable portion finding its way back to the land in some form; in addition to which, imported corn, meat, and other materials will contribute something to the restoration of our own cultivated land. It is at the same time certain that so much of the refuse matters of our towns as becomes diluted with water in the degree recognized under the present sewerage system will be applicable as manure, on the large scale, only to succulent crops, and especially to grass-land; and, so far as this is the case, they will of course not directly contribute to the restoration to the land under tillage, of the mineral constituents sent from it in its produce of corn and meat. When other descriptions of produce than corn and meat, such as roots, hay, or straw, are largely sold, compensation is generally made by the return to the land of stable- or town-manures of some kind. If this be not done, the loss of mineral constituents may indeed be very considerable.

In conclusion, whilst the authors insisted upon the importance of applying to agricultural purposes as much as possible of the valuable manuring matters of our towns, they at the same time believed that modern practices, taken as a whole, did not tend to exhaustion in anything like the degree that had been supposed by some.

On Purifying Towns from Sewage by means of Dry Cloacæ. *By* Dr. J. H. Lloyd.

On the Proportion of Tin present in Tea-Lead. *By* Dr. S. Macadam.

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* The accuracy of some of these analyses, however, is admitted as open to question: see Report by Magnus, Ann. d. Landwirthschaft, xiv. 2.

On the Proportion of Arsenic present in Paper-Hangings. *By* Dr. S. Macadam.

The author had been led to the investigation of this subject by hearing of cases of arsenical poisonings through remaining in rooms with green paperhangings. In all these cases of which he had heard, the patients soon recovered on being removed from one room to another. The question whether the arsenic in green paperhangings was injurious to health very much resembled the question regarding lead, in which it had been stated that a small quantity, though not affecting one person, might act very injuriously upon another. In most of the green paperhangings the arsenic was present in the condition of a rough powder. In some cases the paper was glazed, which had the effect of protecting the arsenic. He had examined several green flock papers, and as a general rule he believed they did not contain arsenic; but all the common descriptions of green paperhangings did. He purchased two packets of envelopes, the bands around which were coloured green. In these two bands he found 3·3 grains of arsenic. The common green paperhangings contained an amount of arsenic varying from 1 to 40 grains per square foot. Taking the mean quantity at 20 grains, a large-sized room would perhaps contain 20,000 grains of arsenic in the paper; a small room 10,000 grains—a quantity capable of producing very serious symptoms. With regard to the mode in which this arsenic could be introduced into the system, it was a question whether arsenic volatilized at ordinary temperatures; but he thought it was not carrying the point too far to suppose that during the damp condition of the paper when being hung, a certain proportion of the arsenic was carried off with the water in the shape of vapour. It was likely to occur also during the night, when the exhalation of the animal system would produce a moisture on the walls as well as the windows, and when a draught was created by the opening of the door in the morning a certain portion of the arsenic might be volatilized. It was possibly more liable to be disturbed by mechanical action, such as dusting, or the rubbing of dresses against the wall, or the grazing of bedhangings against the paper. In such cases the arsenic fell in fine dust upon the carpets, and whenever the carpets were brushed the small particles would fly about and be inhaled. He had not met with any case of death through arsenical poisonings from paperhangings, but he believed it was a medical fact that arsenic taken into the system, even in very small quantities, would soon undermine the health.

On an Economical Mode of boiling Rags, &c. with Alkaline Ley. *By* Dr. S. Macadam.

On the Separation of Ammonia from Coal-gas. *By* W. Marriott.

In the manufacture of coal-gas a large quantity of ammonia is generated along with the permanent gases. The greater portion of the ammonia is separated by cooling or scrubbing, but still a considerable portion passes through the lime or oxide purifier, and so passes along with the gas as caustic ammonia.

Gas-managers are fully aware of the desirability of removing the ammonia, and many processes have been devised for this purpose, some of which are in operation in different gas-works.

Of all the substances which have been used for this purpose sulphuric acid is perhaps the simplest in its application, and, space and economy considered, the quickest in its removal of the ammonia. But there is one great objection in the use of strong sulphuric acid, namely, that it diminishes the illuminating power of the gas by absorbing the rich hydrocarbons.

If gas is allowed for a length of time to pass through sulphuric acid, a point is reached when no more of the hydrocarbons are absorbed, after which the gas may be passed through the acid without injury to its illuminating power.

Acid so prepared is saturated with carbonaceous matter, and if filtered and evaporated to dryness, a mass of carbon is left in the dish.

Now, sulphuric acid so prepared, though it has lost its injurious action on the gas, retains its affinity for the ammonia.

It is the above principle of saturating the sulphuric acid with carbonaceous matter which is applied in the material we now use extensively for separating the ammonia from coal-gas, with this improvement, that the acid instead of being in the liquid state is solid, and is at once in the purifier converted into crystallized sulphate of ammonia.

In saturating sulphuric acid with carbon it is not necessary to use the gaseous hydrocarbons, as almost any vegetable matter will do; sawdust is used. The material is prepared by heating together, at a temperature of about 280° Fahr., equal weights of sulphuric acid, sp. gr. 1700, and sawdust.

At that temperature the organic matter of the sawdust is broken up, and the carbon eliminated solidifies the acid; at the same time the acid dissolves as much carbonaceous matter as it will take up.

The author cannot say what is the organic compound dissolved by the acid, only that in this form of saturation the acid does not in the least injure the illuminating power of the gases passed through it.

On account of the immense surface of acid exposed to the gas when so prepared, we are not surprised to find that the ammonia is separated from the gas instantly it comes in contact with it; in fact, where we are passing from 1 to 3 millions feet of gas in 24 hours, we cannot detect any ammonia until the material is saturated to within 1 or 2 inches of the surface.

The material being very porous, offers very little obstruction to the passage of the gas, and so scarcely increases the pressure.

All those who are engaged in the manufacture of sulphate of ammonia from the ammoniacal liquor obtained from gas-works, well know the great loss of this salt carried away by the steam, either in evaporating a solution to the crystallizing point, or in passing the ammoniacal vapours through the acid. On the large scale the loss is from 10 to 20 per cent.

In the acid prepared as already stated, and converted into sulphate of ammonia, at the temperature of the gas as it passes through the purifier there is no loss; for every equivalent of sulphuric acid used, an equivalent of sulphate of ammonia is received. In an economical point of view this is a great saving; but there is still further economy in the labour, because the very process of removing the ammonia from the gas converts it into sulphate of ammonia ready for the market.

The material as discharged from the purifier contains from 50 to 60 per cent. of sulphate of ammonia applicable for manure purposes.

The author claimed no novelty, either in the use of sulphuric acid alone or mixed with sawdust, but thought its application as a free acid, when saturated with carbonaceous matter, might be of interest to the Section.

On Madder Photographs. *By* JOHN MERCER, *F.R.S.*

On Photographic Spectra of the Electric Light. *By* Professor W. A. MILLER, *M.D., F.R.S.*

The apparatus by which the spectra may be photographed consists of an ordinary camera obscura attached to the end of a long wooden tube, which opens into a cylindrical box, within which is a prism glass, or a hollow prism filled with bisulphide of carbon. If the prism be so adjusted as to throw the solar rays, reflected from a heliostat, upon the screen of a camera, and the wires which transmit the sparks from Ruhmkorff's coil are placed in front of the uncovered portion of the slit, the two spectra are simultaneously impressed. The solar beam is easily intercepted at the proper time by means of a small screen, and the electric spectrum is allowed to continue its action for two or three, or six minutes, as may be necessary. The author did not find that anything was gained in distinctness by interposing a lens of short focus between the slit and the wire which supplied the sparks, with the view of rendering the rays of the electric light parallel like those of the sun, owing to the absorbent action of the glass weakening the photographic effect; and the flickering motion of the sparks being magnified by the lens, rendered the lines less distinct than when the lens was not used. Although with each of the metals (including platinum, gold, silver, copper, zinc, aluminum, magnesium, iron), when the spark was taken in air, he obtained decided photographs, it appeared that in each case the impressed spectrum was very nearly the same, proving that few of the lines produced were those which were characteristic of the metal. The peculiar lines of the metal seemed chiefly to be confined to the visible portion of the spectrum, and these had little or no photographic power. This was singularly exemplified by repeating the experiment upon the same metal in air, in a continuous current of pure hydrogen. Iron, for example, gave, in hydrogen, a spectrum in which a bright orange and a strong green band were visible, besides a few faint lines in the blue part of the spectrum. Although the light produced by the action of the coil was allowed to fall for ten minutes upon a sensitive collodion surface, scarcely a trace of any action was procured; whilst, in five minutes, in the air, a powerful impression of numerous bands was obtained. It was remarked by Mr. Talbot that, in the spectra of coloured flames, the nature of the acid did not influence the position of the bright lines of the spectrum, which he found was dependent upon the metal employed; and this remark has been confirmed by all subsequent observers. But the case is very different in the absorption-bands produced by the vapours of coloured bodies,—there the nature of both constituents of the compound is essentially connected with the production of absorptive bands. Chlorine, combined with hydrogen, gave no bands by absorption in any moderate thickness. Chlorous acid and peroxide of chlorine both produced the same set of bands, while hypochlorous acid, although a strongly coloured vapour and containing the same elements, oxygen and chlorine, produced no absorption-bands. Again, the brownish-red vapour of perchloride of iron produced no absorption-bands; but when converted into vapour in a flame, the iron showed bands independent of the form in which it occurred combined. These anomalies appear to admit of an easy explanation on the supposition that, in any case, the compound employed is decomposed in the flame, either simply by the high temperature, just as water is, as shown by Grove, or in other cases by the reducing action of the burning bodies, which supply the flame, upon the metallic salt introduced into the flame. In the voltaic pile the decomposition must of necessity take place by electric action. The compound gases, protoxide and binoxide of nitrogen, give, when electrified, the same series of bright bands (as Plücker has shown) which their constituents when combined furnish. Aqueous vapour always gives the bright lines due to hydrogen; and hydrochloric acid the mixed system of lines which would be produced by hydrogen and chlorine. The reducing influence of the hydrogen and other combustible constituents of the burning body would decompose the salt, liberating the metal, which would immediately become oxidized or carried off in the ascending current. There was obviously a marked difference between the effect of intense ignition upon most of the metallic and the non-metallic bodies. The observations of Plücker upon the spectra of iodine, bromine, and chlorine show that they give, when ignited, a very different series of bands from those which they furnished by absorption, as Dr. Gladstone has already pointed out; but it is interesting to remark that in the case of hydrogen, which, chemically, is so similar to a metal, we have a comparatively simple spectrum, in which the three principal bright lines correspond to Fraunhofer's dark lines C, F, and G. It was, however, to be specially noted that the hydrogen occasioned no perceptible absorption-bands at ordinary temperatures in such thickness as we could command in our experiments, and the vapour of boiling mercury was also destitute of any absorptive action, although, when ignited by the electric spark, it gave a characteristic and brilliant series of dark bands. The following experiment suggested itself as a direct test of Kirchhoff's theory. Two gas-burners, into which were introduced chloride of sodium on the wick of the spirit-lamp, were placed so as to illuminate equally the opposite sides of a sheet of paper partially greased. The rays of the electric light screened from the photometric surface, suitably protected, were made to traverse one of the flames. If the yellow rays of the light were absorbed by the sodium flame, the light emitted laterally by the flame should be sensibly increased. The experiment, however, failed to indicate any such increase in the brilliancy of the flame, possibly because the eye was not sufficiently sensitive to detect the slight difference which was to be expected.

On Atmospheric Ozone. By Dr. Moffat.

The results given were from the observations of ten years, taken at Hawarden at a height of 260 feet above the level of the sea. The quantity of ozone is greater with decreasing readings of the barometer and when the readings are *below* the mean, than with increasing readings and when they are above the mean, and greater when the range of the barometer and the number of its oscillations are above the mean. It is greater when the mean daily temperature and dew-point temperature are above the mean. Ozone is at a minimum with the wind from points north of S.E. and N.W., and at a maximum with the wind from points south of these; it is also at a maximum when the wind is above its mean force. When rain is above the mean quantity ozone is also above the mean, and also with hail; but it is below the mean with snow and sleet. With fog it is below the mean, above it with cirri, halos, auroræ, and the zodiacal light, but below it with thunder. It is in greater quantity with negative than with positive electricity. Ozone periods so frequently commence with the wind from S.E. points of the compass, and so often terminate with the wind in N.W. points, that these may be called their points of commencement and termination. They may also be said to commence with decreasing readings of the barometer and increase of temperature, and to terminate with increasing readings and decrease of temperature. The quantity of ozone is also greater in the night than in the day. It is greater with new and full moon than during the first and last quarters; and it also varies with the seasons, being greater in the winter and spring months than in summer and autumn. The quantity of ozone varies with the locality; it is greater on the sea-shore than at inland places, and it also increases in quantity with increase of elevation. It is greater in the open country than in towns and villages; and it is at 0 in drains and cesspools and their vicinity, and, in short, at every place where the products of putrefaction or combustion are in sufficient quantity to decompose it. Although these results are from Hawarden observations only, they are supported by observations taken at other places. Differences at individual stations may be attributed to purely local causes. Ozone is a highly oxidized body, and it is easily decomposed by oxidable substances. If test-paper prepared with iodide of potassium be exposed in a locality where these substances are at a minimum, it will in time become brown, and ozone will be at its maximum. If a similar paper be placed in a locality where the quantity of oxidable substances is at its maximum, it will remain white, and ozone will be at a minimum; and if a brown paper be put in the latter place, it will lose its colour, sulphuretted hydrogen being the decolorizing agent. On the sea and the sea-shore ozone is at its maximum, because the products of putrefaction are there small in quantity, and the wind which blows over the ocean is the ozoniferous current. On the land the products of decomposition are at their maximum, hence the current of air that passes over it is non-ozoniferous. Indeed all the conditions of an ozone period are those of the equatorial or ocean current of the atmosphere, and the conditions of a no-ozone period are those of the polar or land current.

Medico-meteorological results give the maximum of diseases with the ozoniferous current, and the maximum of deaths with the no-ozone current, but the diseases may be attributed rather to the vicissitudes of weather than to ozone. As the land or polar current of the air is the lower strata in motion, and the ocean or equatorial current the motion of the higher strata, there ought to be an analogy in a medico-meteorological sense between them, and so we find that the maximum of deaths takes place in the lower strata with minimum of ozone, and the minimum of deaths in the higher strata with maximum of ozone. The calm is also a no-ozone period. During continued calms the products of putrefaction accumulate in the lower strata of the atmosphere and produce diseases of an epidemic nature. A cholera period is a calm and a no-ozone period; and cholera periods terminate with the setting in of the ozoniferous current. In conducting ozone observations, it must be borne in mind that light causes coloration of the test-papers, and that moisture, sulphuretted hydrogen and ammonia cause loss of colour.

On Sulphuretted Hydrogen as a Product of Putrefaction. *By* Dr. Moffat.

The author had enclosed portions of animal and vegetable matter in tin boxes, and through slits in the lids, test-papers prepared with carbonate of lead and with iodine were introduced to half their length. The action of sulphuretted hydrogen was decisively shown, both in the case of the animal and the vegetable matters.

Dr. Moffat had found the iodine test-paper the most sensitive, and by means of it he had often detected the gas in sick rooms and fever rooms.

On the Solvent Power of Strong and Weak Solutions of the Alkaline Carbonates on Uric Acid Calculi. By William Roberts, *B.A., M.D. Lond., Physician to the Manchester Royal Infirmary.*

The design of the author was to show the fallacy of certain experiments that had been made on the solubility of uric acid calculi in solutions of the alkaline carbonates, and to furnish some exact data on which to estimate the rate at which it is possible to effect dissolution of these calculi by alkaline carbonates.

About twenty years ago the French Academy appointed a Commission, composed of MM. Gay-Lussac and Pelouze, to inquire and report on a number of conflicting communications that had been made to it by the advocates of solvents for urinary calculi and their opponents.

This Commission reported in 1842 to this effect:—They exposed numerous urinary calculi for a whole year to the contact of solutions of the alkaline carbonates containing from 273 to 546 grains to the pint. None of these were dissolved; and some were not diminished in bulk. Their loss of weight varied from a quarter to one-half.

In another experiment they passed 110 gallons of a solution containing a twentieth of its weight of carbonate of soda, in the course of three months, over a number of fragments placed at the bottom of a glass funnel. The bulk of most of these was not diminished, and their loss of weight varied from 10 to 60 per cent.

They then tried experiments on the living body, by passing currents of the solvent through the bladder at blood-heat by the double catheter. Here is a sample of their results. A patient who had been subjected to lithotrity, and whose stone was known to be uric acid, had at different times 55 gallons of a solution of carbonate of soda containing 132 grains to the pint, passed over a large remaining fragment which had been carefully measured. This enormous mass of liquid produced no diminution in the bulk of the fragment; its only effect was to soften the surface*.

The conclusions of this report were wholly adverse to the advocates of solution; and they were formally adopted by the Academy.

The experiments, however, have a defect—the solutions used were too concentrated, and this circumstance vitiates the whole inquiry. The author found that very weak solutions of the alkaline carbonates dissolved uric acid calculi with considerable rapidity, while stronger ones altogether failed. In order to decide what strength of solution had most solvent power, fragments of uric acid, weighing from 40 to 112 grains, were placed in 10-oz. phials, and solutions of carbonate of soda and potash of various strengths were passed over them at blood-heat. The experiments were continued day and night; and the daily flow of solvent varied from six to fifteen pints.

Operating in this way, it was found that above a strength of 120 grains to the pint there was no dissolution; and even with 80 grains to the pint there was only a little; but solutions of 50 and 60 grains to the pint dissolved the fragments freely. The cause of this difference was found to lie in a coat or crust of white matter which encased the stone in the stronger solutions. At and above 120 grains to the pint, this coat was dense and tough, and could not be wholly detached from the subjacent surface. With 80 grains to the pint it was brittle, and easily detached like a layer of whitewash. With 60 grains to the pint and under, either no crust formed at all, and the stone was dissolved clean with a water-worn appearance, or it was only represented by a few loose flakes scattered here and there over the surface, and offering no impediment to dissolution. This coating or crust was found essentially to consist of biurate of potash or soda, and its formation depended on the fact that the alkaline biurates are almost insoluble in any but very weak solutions of the alkaline carbonates. In the strong solution, the biurate remains undissolved and encases the stone in an insoluble investment, while in weaker ones it is dissolved as fast as it is formed, the surface of the stone remains clean, and dissolution proceeds without impediment.

* Comptes Rendus, 1842, p. 429.

The following Tables exhibit the results of forty-eight day experiments:—

TABLE I.—Uric Acid and Carbonate of Soda (Sod. Carb. Exsiccat. of the shops).

Strength of solution.	Flow per 24 hours.	No. of Obs.	Daily average loss of weight per cent.	Remarks.
240 grains per pint.	6 pints	2	0	Covered with a dense coating of biurate.
120 „	6 „	2	0	Covered with a dense white coat.
60 „	14 „	2	14·3 per cent.	Covered with a loose white crust, which was removed before weighing.
30 „	15 „	4	10·9 } 10·3 „	Dissolved clean.
30 „	8 „	2	10·2 }	
30 „	5 „	2	9·8 }	

TABLE II.—Uric Acid and Carbonate of Potash.

Strength of the solution.	Flow per 24 hours.	No. of Obs.	Daily average loss of weight per cent.	Remarks.
240 grains per pint.	6 pints	1	0	Covered with a tenacious white coat as if of paint.
120 „	6 „	3	0	Covered with a less dense coating. After detaching this and wiping, there was a loss of weight of 7·1 per cent.
80 „	6 „	2	9·8	Covered with a loose detachable white crust.
60 „	14 „	2	19·0 } 20·2	Surface clean.
60 „	6 „	5	21·4 }	Loose flakes in spots.
40 „	6 „	3	15·6	Sometimes a few loose flakes where the fragment rested.
30 „	15 „	4	13·0 } 11·9	Dissolved clean: occasionally a few loose flakes.
30 „	8 „	2	15·0 }	
30 „	4 „	2	9·5 }	
30 „	6 „	4	10·2 }	
20 „	6 „	3	11·0	Dissolved clean.
10 „	6 „	3	6·5	Dissolved clean.

On Perchloric Acid and its Hydrates. *By* Professor ROSCOE.

All the knowledge we possess of the quantitive relations of perchloric acid is the determination of the composition of the potassium salt, first analysed by Stadion, 1816, and afterwards by many other chemists. The perchloric anhydride has not been isolated, and no analysis of the aqueous acid has ever been made. We can only account for the neglect with which chemists have treated the highest and yet the most stable of the oxides of chlorine by the fact that the preparation of the acid in larger quantities has been attended with great difficulties. The best method for preparing aqueous perchloric acid is to decompose chlorate of potassium with hydrofluosilicic acid, and to boil down the chloric acid thus obtained; this splits up into lower oxides of chlorine, which escape in the gaseous state, impure perchloric acid being left behind, which is purified by distillation. The acid thus obtained is in appearance not to be distinguished from oil of vitriol, being a colourless, heavy, thick, oily, corrosive liquid, giving off on heating dense white fumes. By heating the aqueous perchloric acid with four times its volume of concentrated sulphuric acid, the latter takes water from the first, dense white fumes are evolved, a yellow mobile liquid distils over, and afterwards thick oily drops appear, which, when coming in contact with the yellow liquid, form the white crystals, previously obtained by Serullas, but in such small quantities that he was unable to analyse the substance, which prepared in this way always contains sulphuric acid, and is therefore not fit for analysis and requires redistillation. Heated, however, to 110° C., the crystals decompose and split up again into the yellow liquid, which distils over at a low temperature, and the thick oily liquid, which remains in the retort. The yellow liquid thus obtained is pure perchloric acid, $Cl\,O_8\,H$, a body not known before, which can be obtained also by distilling one atom of perchlorate of potassium with four atoms of sulphuric acid. In the pure state it is perfectly colourless, but as commonly prepared it is slightly yellow, owing to the presence of lower oxides of chlorine. Perchloric acid is one of the most powerful oxidizing agents known: a single drop brought into contact with charcoal, paper, wood, alcohol, &c., immediately causes explosive combustion, in violence not falling short of the decomposition of chloride of nitrogen; and brought on the skin wounds are produced, which do not heal for weeks. Like nitric acid it cannot be distilled without decomposition, but it darkens, and ultimately decomposes with explosion. It cannot be kept for any length of time; for even when sealed up in glass bulbs which are placed at the ordinary temperature in the dark, it decomposes suddenly after some time, breaking the vessel containing it. It mixes with water with a hissing noise and evolution of heat, forming the same crystals which were mentioned before, and were used for preparing the pure acid. These crystals are the monohydrated perchloric acid, $Cl\,O_8\,H+H_2\,O_2$. They melt at 50° C., and heated to 110° C. split up in pure perchloric acid, which distils over, and an oily liquid boiling at 200°, which is also obtained by boiling aqueous perchloric acid till dense white fumes are given off. This oily acid has a constant composition, containing 72·3 per cent. of pure perchloric acid and 27·7 per cent. of water. This per-centage corresponds, however, to no definite hydrate of simple atomic composition; and therefore this acid follows the same general relations respecting composition and boiling-point which, as I have shown previously, hold good for so many other aqueous acids, namely, that the phenomenon of constant boiling-point and constant composition depends chiefly upon physical and not upon chemical attractions.

On Vesicular Structure in Copper. By Drs. Russell *and* Matthiessen.

The authors proved by numerous experiments that the vesicular structure is caused by the action of carbon or sulphur on the suboxide dissolved in melted copper.

On certain Difficulties in the way of separating Gold from Quartz. By Dr. Smith *of Sydney.*

In Australia the usual plan is to reduce the quartz to powder by Cornish stampers, a stream of water being allowed to flow through the stamp box during the operation. The pounded quartz is carried by the stream through fine gratings, and then along an inclined plane supplied with various contrivances, such as blanket stuff and plates of copper rubbed over with mercury, for detaining the gold. The stream is next conducted into the basin of a Chilian mill, where the "pulp" is ground up with mercury. These operations are for the most part so successful as to leave not more than half an ounce of gold in a ton of "tailings." But this successful result is only attained when the quartz is free from pyrites. When pyrites is present, particularly a black amorphous variety (found by Dr. Leibius to contain disulphide of copper and sesquisulphide of iron), there is a notable loss both of gold and mercury in the process of amalgamation. In the basin of the Chilian mill a greyish-black scum might then be seen, which contains mercury and gold in fine division, together with various components of the pyritous quartz, buoyed up by the entanglement of air. The action upon the mercury appeared to be chiefly mechanical, but also in some degree chemical, a small portion of sulphide of mercury being found in the scum, while the gold extracted contained a much larger proportion of copper than is usual with Australian gold. The Australian miners appeared to have hit on no economical mode of separating the gold from pyritous quartz, so as to avoid this loss.

On a Specimen of Meteoric Iron from Mexico. By Professor TENNANT.

On the Cohesion-Figures of Liquids. By CHARLES TOMLINSON.

Regarding solution as a case of adhesion, the author showed that when a drop of an independent liquid (*i. e.* not a solution) is placed on the surface of another independent liquid, such as water, a struggle takes place between them. The particles of the drop endeavour to maintain their cohesion, the adhesion of the surface tends to overcome it; hence a well-defined figure, named by the author a *cohesion-figure*, and regarded as the resultant of the cohesion of the liquid, its density, and the adhesion of the surface. For example, if a drop of oil of lavender be gently delivered to the surface of water in a chemically clean glass, about $3\frac{1}{2}$ inches in diameter, it is spread out by the adhesion of the surface into a well-defined film; cohesion then endeavours to reassert itself, and a struggle takes place between the two forces, the result being a beautiful complicated pattern resembling Carrigeen moss. The cohesion-figures of other oils, fixed and volatile, of creosote, ether, alcohol, naphtha, &c. were shown experimentally, or in the form of large diagrams. In order to produce these figures, the glass vessels and the water must be chemically clean. The figures present a variety of novel and beautiful effects, both as to form and colour, and are likely to prove highly suggestive to the pattern-designer. Moreover, the forms being typical of the substances, a ready means is thus afforded of detecting adulteration.

On the Composition of Crystallized Moroxite, from Jumillo, near Alicante. By DR. VOELCKER, *F.C.S.*

Beautifully crystallized moroxite occurs in large quantities at Jumillo in Spain. Selected crystals of this mineral, analysed by the author, give the following results:—

Water of combination	·298
Phosphoric acid	37·024
Lime	52·954
Magnesia	·269
Oxide of iron	1·170
Alumina	·943
Oxides of cerium (impure oxides)	1·790
Fluorides of sodium and potassium	1·033
Chlorine	trace
Silica	·340
Fluorine and loss	4·179
	100·000

These constituents, combined with each other, give—

Water of combination		·298
Tribasic phosphate of lime	PO_5 37·024	
	CO 43·194	
		80·218
Magnesia		·269
Oxide of iron		1·170
Alumina		·943
Oxides of cerium		1·790
Fluoride of sodium and potassium		1·033
Silica		·340
Fluoride of calcium		13·489
		99·550

The oxide of cerium is not present in the form of Kryptolite, since the analysis was made with perfectly transparent light-green-coloured crystals.

The matrix in which the moroxite crystals are imbedded consists almost entirely of calc-spar.

On the Composition and Properties of the Water of Loch Katrine, as supplied in Glasgow. By Dr. WALLACE, *F.C.S.*

The water of Loch Katrine is well known to be remarkably pure, and to have the property of acting upon lead more extensively than any other natural water known, if we except rain-water. This latter circumstance induced several of our most eminent chemists to express the opinion that danger to the health of the people of Glasgow might arise from the introduction of the water.

The distance of the lake from the city is about 35 miles, and the author shows that the water becomes altered very considerably in composition during its transit. A minute and careful analysis of the water was made in February last; and for comparison an analysis of the true Loch Katrine water, made in the spring of 1854, is also given, the numbers representing grains per gallon.

	Loch Katrine.	Glasgow.
Lime	·19	·47
Magnesia	·10	·12
Sulphuric acid	·33	·36
Chlorine	·33	·30
Alkalies and carbonic acid	·12	·51
Alumina and phosphates	·10	·16
Oxide of iron	—	trace
Silica	·01	·06
Organic matter	·80	·84
	1·98	2·82

In the Loch Katrine water no carbonate of lime was found, while a direct determination of this compound in the Glasgow water gave ·68 grain per gallon. This carbonate of lime is supposed to be derived from sandstone and other rocks through which the water flows.

Loch Katrine water gave 7·5, and Glasgow water 8·5 cubic inches of gas per gallon, which contained in 100 parts—

	Loch Katrine.	Glasgow.
Carbonic acid	1·0	4·5
Oxygen	33·4	29·9
Nitrogen	65·6	65·6
	100	100

The difference in the total quantity of gases may be owing to variation of temperature. The increase in the carbonic acid, accompanied by a corresponding decrease in the oxygen, appears to be owing to the oxidation of organic matter, a similar change occurring when the Loch Katrine water is kept in a closed vessel for a week or two.

Experiments on the action of the Glasgow water on lead show it to be much less active in this respect than the original water of Loch Katrine, the quantity dissolved during the first twenty-four hours being about one-third, and the ultimate result after several weeks, the water being renewed every twenty-four hours, rather more than half of the quantity dissolved by the original water under similar circumstances. At the end of a month the proportion of lead dissolved by the Glasgow water appears to remain steady at $\frac{1}{10}$th of a grain of lead per gallon, a quantity that is just upon the verge of danger.

On the large scale, with pipes and cisterns in actual use, the proportions of lead dissolved were smaller. Three sets of experiments were made; with an old $\frac{3}{4}$-inch pipe previously employed for two years for the conveyaucc of Clyde water, a new $\frac{1}{2}$-inch pipe, and a new cistern exposing $2\frac{1}{2}$ square feet of surface to each cubic foot of water. Observations were commenced after the new pipe and cistern had been in use for several weeks, and were continued for about a month, the water being changed every twenty-four hours. The average quantity of lead dissolved in twenty-four hours was

In the old pipe $\frac{1}{25}$ grain per gallon.
In the new pipe $\frac{1}{13}$ grain per gallon.
In the cistern $\frac{1}{19}$ grain per gallon.

The greater amount dissolved in the new pipe than in the cistern depends upon the larger extent of surface exposed, in the one case 31, in the other only $2\frac{1}{2}$ square feet to each cubic foot of water.

The quantities of lead dissolved, although considerably below the proportions considered actually dangerous, are, nevertheless, somewhat alarming; but it must be borne in mind that the water seldom remains in the pipes more than ten hours, and that during the night when the temperature is lowest; and that in Glasgow the water is usually supplied direct from the street mains, without passing through cisterns.

The results obtained by Dr. Wallace may be reduced to the following summary:—1st, the water-supply of Glasgow is very sensibly harder, and acts with considerably less energy on lead than the water of Loch Katrine; and 2nd, the amount of lead taken up from pipes and cisterns at the present time is not such as to give rise to serious apprehensions.

On an Apparatus for the rapid Separation and Measurement of Gases. By Drs. Williamson *and* Russell.

GEOLOGY.

Address by Sir Roderick Impey Murchison, *D.C.L., LL.D., F.R.S., Director-General of the Geological Survey of the United Kingdom, President of the Section.*

Although I have had the honour of presiding over the geologists of the British Association at several previous Meetings since our first gathering at York, now thirty years ago, I have never been called upon to open the business of this Section with an address; this custom having been introduced since I last occupied the geological chair at Glasgow, in 1855.

The addresses of my immediate predecessors, and the last anniversary discourse of the President of the Geological Society of London, have embraced so much of the recent progress of our science in many branches, that it would be superfluous on my part to go over many topics again which have been already well treated.

Thus, it is needless that I should occupy your time by alluding to the engrossing subject of the most recent natural operations with which the geologist has to deal, and which connect his labours with those of the ethnologist. On this head I will only say that, having carefully examined the detrital accumulations forming the ancient banks of the river Somme in France, I am as complete a believer in the commixture in that ancient alluvium of the works of man with the reliquiæ of extinct animals, as their meritorious discoverer, M. Boucher de Perthes, or as their expounders, Prestwich, Lyell, and others. I may, however, express my gratification in learning that our own country is now affording proofs of similar intermixture both in Bedfordshire, Lincolnshire, and other counties; and, possibly, at this Meeting we may have to record additional evidences on this highly interesting topic.

But I pass at once from any consideration of these recent accumulations, and, indeed, of all tertiary rocks; and, as a brief space of time only is at my disposal, I will now merely lay before you a concise retrospect of the progress which has latterly been made in the development of one great branch of our science. I confine myself then to the consideration of those primeval rocks with which my own researches have for many years been most connected, with a few allusions only to metamorphism, and certain metalliferous productions, &c.

There is, indeed, a peculiar fitness in now dwelling more especially on the ancient rocks, inasmuch as Manchester is surrounded by some of them, whilst, with the exception of certain groups of erratic blocks and drifts, no deposits occur within the reach of short excursions from hence, which are either of secondary or tertiary age.

Let us, then, take a retrospective view of the progress which has been made in the classification and delineation of the older rocks since the Association first assembled at York in 1831. At that time, as every old geologist knows, no attempt had been made to unravel the order or characters of the formations which rise from beneath the Old Red Sandstone. In that year Sedgwick was only beginning to make his first inroads into those mountains of North Wales, the intricacies of which he finally so well elaborated, whilst I only brought to that, our earliest assembly, the first fruits of observations in Herefordshire, Brecon, Radnor, and Shropshire, which led me to work out an order which has since been generally adopted.

At that time the terms 'Cambrian,' 'Silurian,' 'Devonian,' and 'Permian,' were not dreamt of; but, acting on the true Baconian principle, their founders and their coadjutors have, after years of toil and comparison, set up such plain landmarks on geological horizons that they have been recognized over many a distant land. Compare the best map of England of the year 1831, or that of Greenough, which had advanced somewhat upon the admirable original classification of our father, William Smith, and see the striking difference between the then existing knowledge and our present acquirements. It is not too much to say that when the British Association first met, all the region on both sides of the Welsh border, and extending to the Irish Channel on the west, was in a state of dire confusion; whilst in Devonshire and Cornwall many of these rocks, which from their crystalline nature were classed and mapped as among the most ancient in the kingdom, have since been shown to be of no higher antiquity than the Old Red Sandstone of Herefordshire.

As to Scotland, where the ancient rocks abound, though their mineral structure, particularly in those of igneous origin, had necessarily been much developed in the country of Hutton, Playfair, Hall, Jameson, and McCulloch, yet the true age of most of its sedimentary rocks and their relations were unknown. Still less had Ireland, another region mainly palæozoic, received any striking portion of that illustration which has since appeared in the excellent general map of Griffith, and which is now being carried to perfection through the labours of the Geological Survey under my colleague Jukes. If such was our benighted state as regarded the order and characters of the older formations at our first Meeting, great was the advance we had made when at our twelfth Meeting we first assembled at Manchester in 1842. Presiding then as I do now over the Geological Section, I showed in an evening lecture how the palæozoic rocks of Silurian, Devonian, and Carboniferous age, as well as those rocks to which I had assigned the name of Permian, were spread over the vast region of Russia in Europe and the Ural Mountains. What, then, are some of the main additions which have been made to our acquaintance with the older rocks in the British Isles since we last visited Manchester?

Commencing with the oldest strata, I may now assume, from the examination of several associates on whose powers of observation as well as my own I rely, that what I asserted at the Aberdeen Meeting in 1859, as the result of several surveys, and what I first put forth at the Glasgow Meeting of 1855, is substantially true. The stratified gneiss of the north-west coast of the Highlands, and of the large island of Lewis and the outer Hebrides, is the fundamental rock of the British Isles, and the precise equivalent of the Laurentian system of Canada, as described by Sir W. Logan. The establishment of this order, which is so clearly exhibited in great natural sections on the west coast of Sutherland and Ross, is of great importance in giving to the science we cultivate a lower datum-line than we previously possessed, as first propounded by myself before the British Association in 1855*.

* See Report of British Association for 1855 (Glasgow Meeting). At that time I was not aware that the same order was developed on a grand scale in Canada, nor do I now know when that order was there first observed by Sir W. Logan. I then (1855) simply put forward the facts as exhibited on the north-west coast of Scotland; viz. the existence of what I termed a lower or "fundamental gneiss," lying far beneath other gneissose and crystalline strata, containing remains which I even then suggested were of Lower Silurian age. Subsequently, in 1859, when accompanied by Professor Ramsay, I adopted, at his sugges-

For hitherto the order of the geological succession, even as seen in the Geological Map of England and Wales or Ireland, as approved by Sir Henry De la Beche and his able coadjutors, Phillips, Ramsay, Jukes, and others, admits no older sediment than the Cambrian of North Wales, whether in its slaty condition in Merioneth and Caernarvon, or in its more altered condition in Anglesea.

The researches in the Highlands have, however, shown that in our own islands, the older palæozoic rocks, properly so called, or those in which the first traces of life have been discovered, do repose, as in the broad regions of the Laurentian Mountains of Canada, upon a grand stratified crystalline foundation, in which both limestones and iron-ores occur subordinate to gneiss. In Scotland, therefore, these earliest gneissic accumulations are now to be marked on our maps by the Greek letter *alpha*, as preceding the Roman *a*, which had been previously applied to the lowest known deposits of England, Wales, and Ireland. Though we must not dogmatise and affirm that these fundamental deposits were in their pristine state absolutely unfurnished with any living things (for Logan and Sterry Hunt, in Canada, have suggested that there they indicate traces of the former life), we may conclude, that in the highly metamorphosed condition in which they are now presented to us in North-western Britain, and associated as they are with much granitic and hornblendic matter, they are, for all purposes of the practical geologist, "azoic rocks." The Cambrian rocks, or second stage in the ascending order as seen reposing on the fundamental gneiss of the north-west of Scotland, are purple and red sandstones and conglomerates forming lofty mountains. These resemble to a great extent portions of the rocks of the same age which are so well known in the Longmynd range of Shropshire, and at Harlech in North Wales, and Bray Head in Ireland.

At Bray Head they have afforded the *Oldhamia*, possibly an Alga, whilst at the Longmynd, in Shropshire, they have yielded to the researches of Mr. Salter some worm-tracks, and the trace of an obscure crustacean.

The Highland rocks of this age, as well as their equivalents, the Huronian rocks of North America, have as yet afforded no trace whatever of former life. And yet such Cambrian rocks are in parts of the Longmynd, and specially in the lofty mountains of the north-western Highlands, much less metamorphosed than many of the crystalline rocks which lie upon them. Rising in the scale of successive deposits, we find a corresponding rise in the signs of former life on reaching that stage in the earlier slaty and schistose rocks in which animal remains begin clearly to show themselves. Thus, the Primordial Zone of M. Barrande is, according to that eminent man, the oldest fauna of the Silurian Basin in Bohemia*.

In the classification adopted by Sir Henry De la Beche and his associates, the Lingula Flags (the equivalent of the Zone Primordiale of Barrande) are similarly placed at the base of the Silurian system. This Primordial Zone is also classed as the Lowest Silurian by De Verneuil, in Spain; by James Hall, Dale Owen and others, in the United States; and by Sir W. Logan, Sterry Hunt, and Billings, in Canada†.

In the last year, M. Barrande has most ably compared the North American Taco-

tion, the word 'Laurentian,' in compliment to my friend Sir William Logan, who had then worked out the order in Canada, and mapped it on a stupendous scale. I stated, however, at the same time, that if a British synonym was to have been taken, I should have proposed the word 'Lewisian,' from the large island of the Lewis, almost wholly composed of this gneiss.

* I learn, however, that in Bohemia Dr. Fritsch has recently discovered strata lying beneath the mass of the Primordial Zone of Barrande, and in rocks hitherto considered azoic the fossil burrows of annelide animals similar to those of our own Longmynd.

† In completing at his own cost a geological survey of Spain, in which he has been occupied for several years, and in the carrying out of which he has determined the width of the sedimentary rocks of the Peninsula (including the Primordial Silurian Zone, discovered by that zealous explorer, M. Casiano de Prado), M. de Verneuil has in the last few months chiefly examined the eastern part of the kingdom where few of the older palæozoic rocks exist. I am, however, informed by him, that Upper Silurian rocks with *Cardiola interrupta*, identical with those of France and Bohemia, occur along the southern flanks of the Pyrenees, and also re-occur in the Sierra Morena, in strata that overlie the great mass of Lower Silurian rocks as formerly described by M. Casiano de Prado and himself. The southern face of the Pyrenees, he further informs me, is specially marked by the display of mural masses of Carboniferous strata, which, succeeding the Devonian rocks, are not arranged in basin-shape, but stand out in vertical or highly inclined positions, and are followed by

nic group of Emmons* with his own primordial Silurian fauna of Bohemia and other parts of Europe; and although that sound palæontologist, Mr. James Hall, has not hitherto quite coincided with M. Barrande in some details†, it is evident that the primordial fauna occurs in many parts of North America. And as the true order of succession has been ascertained, we now know that the Taconic group is of the same age as the lower Wisconsin beds described by Dale Owen, with their *Paradoxides, Dikelocephalus,* &c., as well as of the lower portion of the Quebec rocks, with their *Conocephalus, Axionellus,* &c., described by Logan and Billings. Of the crystalline schists of Massachusetts, containing the noble specimen of *Paradoxides* described by W. Rogers, and of the Vermont beds, with their *Oleni,* it follows that the Primordial Silurian Zone of Barrande (the lower Lingula-flags of Britain) is largely represented in North America, however it may occupy an inverted position in some cases, and in others be altered into crystalline rocks.

In determining this question due regard has been had to the great convulsions, inversions, and breaks to which these ancient rocks of North America have been subjected, as described by Professors Henry and W. Rogers.

In an able review of this subject, Mr. Sterry Hunt thus expresses himself:—"We regard the whole Quebec group, with its underlying primordial shales, as the greatly developed representatives of the Potsdam and Calciferous groups (with part of that of Chazy), and the true base of the Silurian system. . . . . The Quebec group, with its underlying shales," this author adds (and he expresses the opinion of Sir W. Logan), "is no other than the Taconic system of Emmons;" which is thus, by these authors, as well as Mr. James Hall, shown to be the natural base of the Silurian rocks in America, as Barrande and De Verneuil have proved it to be on the continent of Europe.

In our own country a valuable enlargement of our acquaintance with the relations of the primordial zone to the overlying members of the Silurian rocks has been made through the personal examination of Mr. Salter, aided by the independent discoveries of organic remains by MM. Homfray and Ashe, of Tremadoc.

It has thus been ascertained that the lower member only of the deposit, which has been hitherto merged under the name of Lingula-flags, can be considered the equivalent of the primordial zone of Bohemia. In North Wales that zone has hitherto been mainly characterized by *Lingula* and the crustaceous *Olenus* and *Paradoxides.* Certain additions having been made to these fossils, Mr. Salter finds that of the whole there are five genera peculiar to the lower zone, and seven which pass upwards from it into the next overlying band or the Tremadoc slate. But the overlying Tremadoc slate, hitherto also grouped with the Lingula-flags, is, through its numerous fossils (many of them of recent discovery), demonstrated to constitute a true lower member of the Llandeilo formation. For, among the trilobites, the well-known Llandeilo forms of *Asaphus* and *Ogygia* range upwards from the very base of these slates. Again, seven or eight other genera of trilobites, which appear here for the first time, are associated with genera of mollusks and encrinites which have lived through the whole Silurian series. Such, for example, are the genera *Calymene, Illænus,* among crustaceans; the *Lingula, Orthis, Bellerophon,* and *Conularia* among mollusks, together with encrinites, corals, and that telling Silurian zoophyte, the Graptolite. By this proof of the community of fossil types, as well as by a clear lithological passage of the beds, these Tremadoc slates are thus shown to be indissolubly connected with the Llandeilo and other Silurian formations above them; whilst, although they also pass down conformably into the zone primordiale, the latter is characterized by the linguloid shells (*Lingulella,* Salter) and by the genera *Olenus, Paradoxides,* and *Dikelocephalus,* which most characterize it in Britain as in other regions‡.

extensive conglomerates and marls of triassic age, and these by deposits charged with fossils of the Lias.

* The Silurian classification was proposed by me in 1835, and in the following year (1836) Dr. Emmons suggested that his black shale rocks, which he called Taconic, were older than any I described.

† Nor are the writings of the Professors W. B. and H. D. Rogers in unison with the opinions of the authors here cited.

‡ In the last edition of 'Siluria' the distinction was drawn between the lower and upper Lingula-flags, but the fauna of the latter is now much enlarged.

I take this opportunity, however, of reiterating the opinion I have expressed in my work 'Siluria,' that to whatever extent the primordial zone of Barrande be distinguished by peculiar fossils in any given tract from the prevalent Lower Silurian types, there exists no valid ground for differing from Barrande, De Verneuil, Logan, James Hall, and others, by separating this rudimentary fauna from that of the great Silurian series of life of which stratigraphically it constitutes the conformable base. And if in Europe but few genera be yet found which are common to this lower zone and the Llandeilo formation (though the *Agnostus* and *Orthis* are common to it and all the Silurian strata), we may not unreasonably attribute the circumstance to the fact that the primordial zone of no one country contains more than a very limited number of distinct forms. May we not, therefore, infer that in the sequel other fossil links, similar to those which are now known to connect the Lower and Upper Silurian series—which I myself at one time supposed to be sharply separated by their organic remains—will be brought to light, and will then zoologically connect the primordial zone with the overlying strata into which it graduates? Let us recollect that a few years only have elapsed since M. de Verneuil was criticised for inserting, in his Table of the Palæozoic Fauna of North America, a number of species as being common to the Lower and Upper Silurian. But now the view of the eminent French Academician has been completely sustained by the discovery in the strata of Anticosti, as worked out by Mr. Billings under the direction of Sir W. Logan, of a group of fossils intermediate in character between those of the Hudson River and Clinton formations, or, in other words, between Lower and Upper Silurian rocks. In like manner, a similar interlacing seems already to have been found in North America between the Quebec group, with its primordial fossils, and the Trenton deposits, which are, as is well known, of the Llandeilo age.

I have thus spoken out upon the fitness of adhering to the classifications decided upon by Sir Henry De la Beche and his associates long before I had any relation to the Geological Survey, and which places the whole of the Lingula-flags of Wales as the natural base of the Silurian rocks. For English geologists should remember that this arrangement is not merely the issue of the view I have long maintained, but is also the matured opinion of those geologists in foreign countries and in our colonies who have not only zealously elaborated the necessary details, but who have also had the opportunities of making the widest comparisons.

On the continent of Europe an interesting addition has been made to our acquaintance with the fauna of one of the older beds of the Lower Silurian rocks, or the Obolus greensand of St. Petersburg*, by our eminent associate, Ehrenberg. He has described and figured† four genera and ten species of microscopic Pteropods, one of which he names *Panderella Silurica*; the generic name being in honour of the distinguished Russian palæontologist, Pander, who collected them. It is well to remark, that as the very grains of this Lower Silurian greensand seem to be in great part made up of these minute organisms, so we recognize, in one of the oldest strata in which animal life has been detected, organisms of the same nature, and not less abundant than those which constitute the deep sea-bottoms of the existing Mediterranean and other seas.

Before I quit the consideration of the older palæozoic rocks, I must remind you that it is through the discovery, by Mr. C. Peach, of certain fossils of Lower Silurian age in the limestones of Sutherland, combined with the order of the strata, observed in the year 1827 by Professor Sedgwick and myself, that the true age of the largest and overlying masses of the crystalline rocks of the Highlands has been fixed. The fossils of the Sutherland limestone are not indeed strictly those of the Lower Silurian of England and Wales, but are analogous to those of the calciferous sand-rock of North America. The *Maclurea* is indeed known in the Silurian limestone of the south of Scotland; but the *Ophileta* and other forms are not found until we reach the horizon of North America. Now, these fossils refer the zone of the Highland limestone and associated quartz-rocks to that portion of the Lower Silurian which forms the natural base of the Trenton series of North America, or the lower part of the Llandeilo formation of Britain. The intermediate formation

* See 'Russia and the Ural Mountains.'

† Monats-Bericht d. König. Akad. der Wiss. Berlin, 18 April, 1861.

—the Lingula "flags" or "zone primordiale" of Bohemia—having no representative in the north-western Highlands, there is necessarily a complete unconformity between the fossil-bearing crystalline limestones and quartz-rocks with the *Maclurea*, *Murchisonia*, *Ophileta*, *Orthis*, *Orthoceratites*, &c., and those Cambrian rocks on which they rest.

A great revolution in the ideas of many an old geologist, including myself, has thus been effected. Strengthened and confirmed as my view has been by the concordant testimony of Ramsay, Harkness, Geikie, James, and others, I have had no hesitation in considering a very large portion of the crystalline strata of the Highlands to be of the same age as some of the older fossiliferous Silurian rocks, whether in the form of slates in Wales, of greywacke-schist in the southern counties of Scotland, or in the conditions of mud and sand at St. Petersburg. The conclusion as respects the correlation of all the older rocks of Scotland has now indeed been summed up by Mr. Geikie and myself in the 'Geological Sketch-Map of Scotland,' which we have just published, and a copy of which is now exhibited*. Not the least interesting part of that production is that which explains the age of all the igneous or trappean rocks of the south of Scotland, as well as all the divisions of the Carboniferous formation, and is exclusively the work of my able colleague.

But if, through the labours of hard-working geologists, we have arrived at a clear idea of the first recognizable traces of life and their sequences, we are yet far from having satisfied our minds as to the *modus operandi* by which whole regions of such deposits have, as in the Highlands, been transmuted into a crystalline slate. Let us therefore hope that, ere this Meeting closes, we may receive instruction from some one of the band of foreign or British geologists who have by their experimental researches been endeavouring to explain the processes by which such wonderful changes in the former condition of sedimentary deposits have been brought to light; such as that by which strata once resembling the incoherent Silurian clay which we see in Russia have been hardened into such rocks as the slaty grauwacke of other regions, and how hard schists of the south of Scotland have been metamorphosed into the crystalline rocks of the Highlands. But why are British geologists to see any difficulty in admitting what I have proposed, that vast breadths of these crystalline stratified rocks of the Highlands are of Lower Silurian age? Many years ago I suggested, after examination, that some of the crystalline rocks near Christiania in Norway were but altered extensions of the Silurian deposits of that region; and, since then, Mr. David Forbes and M. Kjerulf have demonstrated the truth of the suggestion. Again, and on a vastly larger scale, we know that in North America all the noted geologists, however they may differ on certain details, agree in recognizing the fact that the vast eastern seaboard range of gneissic and micaceous schists is made up of metamorphosed strata, superior even to the lowest of the Silurian rocks. Logan, Rogers, Hall, and Sterry Hunt are decidedly of this opinion; and the point has been most ably and clearly set before the public by the last-mentioned of these geologists†, who, being himself an accomplished chemist, has given us some good illustrations of the probable *modus operandi* in the bringing about of these changes.

The importance of the inquiries to be made by chemical geologists into this branch of our science was not lost upon the earlier members of the British Association. Even in the year 1833, a committee was appointed to endeavour to illustrate the phenomena of the metamorphism of rocks by experiments carried on in iron-furnaces. After a series of trials on various mineral substances, the Rev. W. Vernon Harcourt, to whom we owed so much at our foundation, has, as the reporter of that committee, been enabled to present to the Association that lucid Report on the actual effect of long-continued heat which is published in our last volume. In referring you to that document, I must, as an old practical field-geologist, express the gratification I feel in seeing that my eminent friend has, in the spirit of true inductive philosophy, arrived, after much experiment and thought, at the same conclusion at which, in common with Sedgwick, Buckland, De la Beche, Phillips, and others in my own country, and with L. von Buch, Elie de Beaumont, and a host of geolo-

* This map is already on sale in Manchester.

† American Journal of Science, May, 1861.

gists abroad, I had long ago arrived in the field. I, therefore, re-echo their voices in repeating the words of Mr. W. Harcourt, "that we are not entitled to presume that the forces which have operated on the earth's crust have always been the same." Looking to the only rational theory which has ever been propounded to account for the great changes in the crust which have taken place in former periods—the existence of an intense central heat which has been secularly more and more repressed by the accumulation of sediment until the surface of the planet was brought into its present comparatively quiescent condition—our first General Secretary has indicated the train of causes, chemical and physical, which resolve some of the difficulties of the problem. He has brought before us, in a compendious digest, the history of the progress which has been made in this branch of our science, by the writings of La Place, Fourier, Von Buch, Fournet, and others, as well as by the experimental researches of Mitscherlich, Berthier, Senarmont, Daubrée, Deville, Delesse, and Durocher. Illustrating his views by reference to chemical changes in the rocks and minerals of our own country, and fortifying his induction by an appeal to his experiments, he arrives at the conclusion, that there existed in former periods a much greater intensity of causation than that which now prevails. His theory is, that whereas now, in the formation of beds, the aqueous action predominates, and the igneous is only represented by a few solfataras, in the most ancient times the action was much more igneous, and that in the intermediate times fire and water divided the empire between them. In a word, he concludes with the expression of the opinion, which my long-continued observation of facts had led me to adopt, "that the nature, force, and progress of the past condition of the earth cannot be *measured* by its existing condition."

In addition to these observations on metamorphism, let me remind you that, on the recommendation of the British Association, other important researches have been carried on by Mr. William Hopkins, our new General Secretary, and in the furnaces of our President, Mr. Fairbairn, on the conductive powers for heat in various mineral substances. Although these experiments have been retarded by a serious accident which befell Mr. Hopkins, they are still in progress, and I learn from him that, without entering into any general discussion as to the probable thickness of the crust of our planet, we may even now affirm, on experimental evidence, that, assuming the observed terrestrial temperature to be due to central heat, the thickness of this crust must be two or three times as great as that which has been usually considered to be indicated by the observed increase of temperature at accessible depths beneath the earth's surface.

Of the Devonian rocks or Old Red Sandstone much might be said, if I were to advert to the details which have been recently worked out in Scotland by Page, Anderson, Mitchell, Powrie, and others; and in England, by the researches of the Rev. W. Symonds, and other members of the Woolhope and Malvern Clubs. But confining myself to general observations, it may be stated that a triple subdivision of that group, which I have shown to hold good over the Continent of Europe as in our own country, seems now to be generally admitted, whilst the history of its southern fauna in Devonshire has recently been graphically and ably elaborated by Mr. Pengelly, in a paper printed in our last volume.

In Herefordshire and Shropshire the passage of the upper members of the Silurian rocks into the inferior strata of the Old Red group has been well shown by Mr. Lightbody, and the fossils of its lower members have been vigorously collected; whilst in Scotland Mr. Geikie and others have shown the upward passage of *its superior* strata into the base of the Carboniferous rocks; and Dr. Anderson announces the finding of shells with crustacea in the lower or grey beds south of the Tay. I may here note, that the point which I have been for some years endeavouring to establish as to the true position of the Caithness flags with their numerous ichthyolites seems to be admitted by my contemporaries. The lamented Hugh Miller considered these ichthyolites as belonging to the lower member of the group, and had good grounds for his views, since at his native place, Cromarty, these fish-beds appear very near the base. But, by following them into Caithness and the Orkneys, I have shown that they occupy a middle position, whilst the true base of the group is the equivalent of the zone with *Cephalaspis, Pteraspis,* and *Pterygotus.*

And here it is right to state that the Upper Silurian rocks, which are clearly represented in Edinburghshire, and which in Lanarkshire seem to graduate upwards into the Lower Old Red or Cephalaspis sandstone, are wanting in the Highlands; thus accounting for the great break which there occurs between the crystallized rocks of Lower Silurian age and the bottom beds of the Old Red Sandstone.

Of the Old Red Sandstone of Scotland and Herefordshire I may be permitted further to observe, that its downward passage into the uppermost Silurian rock, and the upward passage of its higher strata into the Carboniferous strata, have been well developed,—the one near Ludlow, chiefly through the labours of Mr. Lightbody; the other in Scotland, through the researches of the Government Geologists, Howell and Geikie, as well as by those of Mr. D. Page and other observers. On this head I may, however, note, what my contemporaries seem now to admit, that the removal of the Caithness flags and their numerous included ichthyolites from the bottom of this group, and their translation to the central part of the system, as first proposed by myself, is correct. In truth, the lower member of this system is now unequivocally proved to be the band with *Cephalaspis, Pteraspis, &c.*, as seen in Scotland, England, and Russia. The great break which has been traced in the south of Scotland by Mr. Geikie between the lower and upper Old Red is thus in perfect harmony with the zoological fact that the central or Caithness fauna is entirely wanting in that region, as in England—as it is indeed in Ireland, where a similar break occurs.

It gratifies me to add, that many new forms of those fossil fishes which so peculiarly characterize the Old Red Sandstone, have been admirably described by Sir Philip de Grey Egerton in the 'Memoirs of the Geological Survey;' and I must remark that it is most fortunate that the eminent Agassiz is here so well represented by my distinguished friend, who stands unquestionably at the head of the fossil ichthyologists of our country.

Very considerable advances have been made in the development of our acquaintance with that system—the Carboniferous—which in the North of England (Yorkshire) has been so well described by Professor Phillips, and with which all practical geologists in and around Manchester are necessarily most interested. The close researches of Mr. Binney, who has from time to time thrown new light on the origin and relations of coal and the component parts of its matrix, established proofs, so long ago as 1840, that great part of our coal-fields was accumulated under marine conditions; the fossils associated with the coal-beds being, not, as had been too generally supposed, of fluviatile or lacustrine character, but the spoils of marine life. Professor Henry Rogers came to the same conclusion with regard to the Appalachian coal-fields in America in 1842. Mr. Binney believes that the plant *Sigillaria* grew in salt water; and it is to be remarked that even in the so-called "freshwater limestones" of Ardwick and Le Botwood, the *Spirorbis* and other marine shells are frequent, whilst many of the shells termed *Cypris* may prove to be species of *Cythere*. Again, in the illustrations of the fossils which occur in the bands of iron-ore in the South Welsh coal-field, Mr. Salter, entering particularly into this question, has shown that in the so-called "Unio-beds" there constantly occurs a shell related to the *Mya* of our coasts, which he terms *Anthracomya*; whilst, as he has stated in the 'Memoirs of the Geological Survey,' just issued, the very Unios of these beds have a peculiar aspect, differing much from that of true freshwater forms. They have, he says, a strongly wrinkled epidermis, which is a mark of the Myadæ, or such burrowing bivalve shells, and not of true Unionidæ; they also differ in the interior, as shown by Professor W. King. Seeing that in these cases quietly deposited limestones with marine shells (some of them indeed of estuary character) rest upon beds of coal, and that in many other cases purely marine limestones alternate frequently with layers of vegetable matter and coal, may we not be led to modify the theory, founded on the sound observation of Sir W. Logan, by which the formation of coal has been rather too exclusively referred to terrestrial and freshwater conditions? May we not rather revert to that more expansive doctrine, which I have long supported, that different operations of nature have brought about the consolidation and alteration of vegetable matter into coal? In other words, that in one tract the coal has been formed by the subsidence *in situ* of vast breadths of former jungles and forests; in another, by the transport of vegetable materials into marine estuaries; in a third case, as in Russia and Scotland (where purely marine limestones alternate with coal), by a succession of oscillations between jungles and the sea; and lastly, by the extensive growth of large plants in shallow seas.

The Geological Map of Edinburghshire, prepared by MM. Howell and Geikie, and recently published, with its lucid explanations, affords indeed the clearest proofs of the frequent alternations of beds of purely marine limestone charged with *Producti* and bands of coal, and is in direct analogy with the coal-fields of the Donetz in Southern Russia*.

In sinking through the extensive coal-tracts around Manchester (at Dukinfield), where one of the shafts already exceeds in depth the deepest of the Durham mines, rigorous attention will, I hope, be paid to the discovery of the fossils which characterize each bed passed through,—not merely to bring about a correctly matured view of the whole history of these interesting accumulations, formed when the surface of our planet was first furnished with abundant vegetation, but also for the practical advantage of the proprietor and miner, who, in certain limited areas, may thus learn where iron-ores and beds of coal are most likely to be persistent. In carrying out his survey-work through the north-western coal-tracts of Lancashire, to which the large or six-inch Ordnance Map has been applied, one of the Secretaries of this Section, Mr. Hull, has done good service in accurately defining the tracts wherein the elevated coal-deposits are covered by drift only, in contradistinction to those which are still surmounted by red rocks of Permian and Triassic age. In seeing that these are eagerly bought by the public, and in recognizing the great use which the six-inch survey has proved in the hands of the geological surveyors in Scotland, our friends in and around Manchester may be led to insist on having that large scale of survey extended to their own important district. By referring to the detailed delineations of the outcrops of all the Carboniferous strata in the counties of Edinburgh, Haddington, Fife, and Linlithgow, as noted by Professor Ramsay and MM. Howell and Geikie, the coal-proprietors of England will doubtless recognize the great value of such determinations.

Concerning the Permian rocks, which were formed towards the close of the long palæozoic era, and constitute a natural sequel to the old Carboniferous deposits, it is to be hoped that we shall here receive apposite illustrations from some of our associates.

When Professor Sedgwick, thirty-four years ago, gave to geologists his excellent Memoir on the Magnesian Limestone of our country, as it ranges from Durham, through Yorkshire, into Nottinghamshire, he not only described the numerous varieties of mineral structure which that rock exhibits, noting at the same time its characteristic fossils, but he also correlated it, and its underlying beds, with the Zechstein, Kupferschiefer, and Rothe-todte-liegende of Germany. But whilst this is the true order in both countries, there is this considerable difference in England, that along the zone where the Magnesian Limestone exists as a mass, and where Sedgwick described it, the inferior member of the group is a thin band of sandstone, usually of a yellow colour (the Pontefract rock of William Smith), which in its southern extremity, near Nottingham, is almost evanescent. In many parts of Germany, on the contrary, and notably in Thuringia and Silesia, the same lower band, with a few intercalated courses of limestone, swells out into enormous thicknesses and even constitutes lofty ridges.

In Russia the series of this age puts on a very different mineral arrangement. There the calcareous bands, containing the very same species of shells as the magnesian limestone of Germany and Britain, are intercalated with pebble-beds, sandstones, marls, and copper ores, so that, although the same lithological order does not prevail as in the Saxon or typical Permian country of the elder German geologists, the group is, through its fossil types, unquestionably the same. It was from the observation of this fact, and from seeing that these deposits, so mixed up, yet so clearly correlated by their animal and vegetable relics, and all superposed to the Carboniferous system, occupied a region twice as large as the British Isles, in which the varieties of structure are best seen in the government of Perm, that I proposed in 1841 that the *whole group* should have the name of 'Permian.'

Of late years various British authors, including King, Howse, and others, have ably described the fossil shells of this deposit as it exists on the eastern side of

* See 'Russia in Europe and the Ural Mountains,' vol. i.

the Penine chain; and recently Mr. Kirkby has produced a carefully written and well-considered memoir, showing the relations of the whole group, by comparing its structure and palæontological contents in Durham with those in South Yorkshire. Whilst, in addition, my associates of the Geological Survey, particularly Mr. Aveline, have been carefully delineating the area of these beds in their northern range from Nottingham through Yorkshire, much yet remains to be done in correlating the Permian rocks lying to the west of the Penine ridge, or where we are now assembled, with their eastern equivalents.

Already, however, great strides have been made towards this desirable end. Thus, Mr. Binney has indicated the succession in the neighbourhood of Manchester, and has shown us that there some of the characteristic fossils of the eastern magnesian limestone exist in red marl and limestones subordinate thereto, and that these are clearly underlain by other red sandstones, shales, and limestones, which he terms Lower Permian. He has further followed these Lower Permian beds to the west and north-west, and finds them expanding into considerable thicknesses at Astley, Scarisbrick, and other places where they overlie the coal-measures, and he has also traced them into Westmoreland, Cumberland, and Dumfriesshire. In the last case he went far to prove that which I suggested many years ago, that the red sandstones of Dumfriesshire, containing the large footprints of chelonians, as described by Sir W. Jardine, are of Lower Permian age.

This view of the relations of the Permian rocks of the north-west has been also taken by Professor Harkness, and this summer he has successfully worked it out, and has definitely applied the Permian classification to large tracts in Cumberland, as explained in a letter to myself. He finds that the breccias and sandstones of Kirkby-Stephen and Appleby, which at the latter place have a thickness of three thousand feet, extend northward on the west side of the Eden (the breccia being replaced by false-bedded sandstones with footprints), and attain near Carlisle the enormous thickness of about five thousand feet. These beds he classes unhesitatingly as Lower Permian, because he finds them to be overlain (near Ormsby) by a group of clays, sandstones, and magnesian limestones, containing peculiar plant-remains and shells of the genus *Schizodus*, representing in his opinion the marl-slate and magnesian limestone of Durham. These, again, support beds equivalent to the Zechstein, and the last are covered by the Triassic sandstone of the Solway.

A very striking fact, noticed by Professor Harkness, and corroborative of earlier researches made by Mr. Binney, is the existence of footprints in the Lower Permian of Cumberland, similar to those of Corncockle Moor in Dumfriesshire, where, from my own observations, including those of last year, these Lower Permian sandstones have, I am convinced, a greater thickness even than that which is assigned to them in Cumberland.

Notwithstanding these discoveries, we have still to show the continuous existence of the Lower Red Sandstone of Shropshire, Worcestershire, and Staffordshire, which I have classed as the lower member of the Permian rocks, and to decide whether it be really such lower member *only*, or is to be regarded as the equivalent of the whole Permian group, under differing mineral conditions. With the extension of the Geological Survey this point will, doubtless, be satisfactorily adjusted, and we shall then know to what part of the series we are to attach the plant-bearing red beds of Coventry and Warwick, described as Permian by Ramsay and his associates. We have also to show that, in its northern course, the lower red sandstone of the central counties, with its calcareous conglomerates, graduates into the succession exhibited at Manchester, thence expanding northwards. Already, however, we have learned that in our own little England, which contains excellent normal as well as variable types of all the palæozoic deposits, there exists proof that the Permian rocks, according to the original definition of the same, present to the observer who examines them to the west as well as to the east of the Penine chain, nearly as great diversities of lithological structure, in this short distance, as those which distinguish the strata of the same age in Eastern Russia in Europe from the original types of the group in Saxony and other parts of Germany.

Geological Survey and Government School of Mines, Mineral Statistics, and Colonial Surveys.—As I preside for the first time over this Section since I was placed at the head of the Geological Survey of Britain, I may be excused for making an allusion to that national establishment, by stating that the public now take a lively interest in it, as proved by a largely increased demand for our maps and their illustrations,—a demand which will, I doubt not, be much augmented by the translation at an early day of many of our field-surveyors from the south-eastern and central parts of England, where they are now chiefly employed, to those northern districts where they will be instrumental in developing the superior mineral wealth of the region.

The Government School of Mines, an offshoot of the Geological Survey, is primarily intended to furnish miners, metallurgists, and geological surveyors with the scientific training necessary for the successful pursuit and progressive advancement of the calling which they respectively pursue; but, at the same time, the lectures and the laboratories are open to all those who seek instruction in physical science for its own sake, by reason of its important application to manufactures and the arts. The experience of ten years has led the Professors to introduce various modifications into their original programme, with the view of adapting the school as clearly as possible to the wants of those two classes of students; and at present, while a definite curriculum, with special rewards for excellence, is provided for those who desire to become mining, metallurgical, and geological associates of the school, every student who attends *a single course of lectures* may by the new rules compete, in the final examination, for the prizes which attach to it only.

Throughout the whole period of the existence of the school, the Professors have given annual courses of evening lectures to working men, which are always fully attended, as a part of their regular duty; and during the past year, several of them have delivered voluntary courses of evening lectures, at a fee so small as to put them within the reach of working men, pupil-teachers, and schoolmasters of primary schools. The Professors thus hope to support to the utmost the great impulse towards the diffusion of a knowledge of physical science through all classes of the community, which has been given through the Department of Science and Art by the Minute of the Committee of Privy Council of the 2nd of June, 1859.

A body like the British Association for the Advancement of Science should, I conceive, not be unaware of a step of such vast importance, and tending so entirely towards the same goal as that to which its own efforts have been and still are constantly directed.

Now, inasmuch as I can trace no record of the teachings of the Government School of Mines in the volumes of the British Association, and as I am convinced that the establishment only requires to be more widely known, in order to extend sound physical knowledge, not merely to miners and geologists, but also to chemists, metallurgists, and naturalists, I have only to remind my audience that this School of Mines, which, owing its origin to Sir Henry De la Beche, has furnished our colonies with some of the most accomplished geological and mining surveyors, and many a manufacturer at home with good chemists and metallurgists, has now for its lecturers men of such eminence, that the names of Hofmann, Percy, Warington Smyth, Willis, Ramsay, Huxley, and Tyndall are alone an earnest of our future success.

In terminating these few allusions to the Geological Survey, and its applications, I gladly seize the opportunity of recording, that in the days of our founder, Sir Henry De la Beche, our institution was greatly benefited in possessing for some years, as one of its leading surveyors, such an accomplished naturalist and skilful geologist as the beloved Assistant General Secretary of the British Association, Professor Phillips, who by his labours threw much new light on the palæontology of Devonshire, who, in the Memoirs of the Survey, has contributed an admirable Monograph on the Silurian and other rocks around the Malvern Hills, and who, by his lectures and writings, is now constantly advancing geological science in the oldest of our British universities.

There is yet one subject connected with the Geological Survey to which I must also call your attention, viz. the mineral statistics of the United Kingdom, as compiled with great care and ability by Mr. Robert Hunt, the Keeper of the Mining Records, and published annually in the Memoirs of our establishment.

These returns made a deep impression on the statists of foreign countries who were assembled last year in London at the International Congress. The Government and members of the legislature are now regularly furnished with reliable information as to our mineral produce, which, until very recently, was not obtainable. By the labours of Mr. Robert Hunt, in sedulously collecting data from all quarters, we now become aware of the fact that we are consuming and exporting about 80 millions of tons of coals annually (a prodigious recent increase, and daily augmenting). Of iron-ore we raise and smelt upwards of 8 millions of tons, producing 3,826,000 tons of pig iron. Of copper-ore we raise from our own mines 236,696 tons, which yield 15,968 tons of metallic copper; and from our native metallic minerals we obtain—of tin, 6695 tons; of lead, 63,525 tons; and of zinc, 4357 tons. The total annual value of our minerals and coals is estimated at £26,993,573, and of that of the metals (the produce of the above minerals) and coals at £37,121,318.

When we turn from the consideration of the home-survey to that of the geological surveys in the numerous colonies of Great Britain, I may well reflect with pleasure on the fact that nearly all the leaders of the latter have been connected with, or have gone out from, our home Geological Survey and the Government School of Mines.

Such were the relations to us of Sir William Logan in Canada, of Professor Oldham in India, with several of his assistants, of Selwyn in Victoria, of my young friend Gould in Tasmania, as well as of Wall in Trinidad; whilst Barrett in Jamaica is a worthy pupil of Professor Sedgwick. Passing over the many interesting results which have arisen out of the examination of these distant lands, we cannot but be struck with the fact, that whilst Hindostan (with the exception of the higher Himalayan mountains) differs so materially in its structure and fossil contents from Europe, Australia (particularly Victoria) presents, in its palæozoic rocks at least, a close analogy to Britain. Thanks to the ability and zeal of Mr. Selwyn, a large portion of this great auriferous colony has been already surveyed and mapped out in the clearest manner. In doing this he has demonstrated that the productive quartzose veinstones, which are the chief matrix of gold, are mainly subordinate to the Lower Silurian slaty rocks, charged with Trilobites and Graptolites, and penetrated by granite, syenite, and volcanic rocks, occupying vast regions. Mr. Selwyn, aided in the palæontology of his large subject by Prof. M'Coy, has also shown how these original auriferous rocks have been worn down at successive periods, one of which abrasions is of pliocene age, another of post-pliocene, and a third the result of existing causes. All these distinctions, as well as the demarcation of the Carboniferous, Oolitic, and other rocks, are clearly set forth. Looking with admiration at the execution of these geological maps, it was with exceeding pain I learnt that some members of the Legislature of Victoria had threatened to curtail their cost, if not to stop their production. As such ill-timed economy would occasion serious regret among all men of science, and would, I know, be also deeply lamented by the enlightened Governor, Sir Henry Barkly, and would at the same time be of lasting disservice to the material advancement of knowledge among the mining classes of the State, let us earnestly hope that the young House of Parliament at Melbourne may not be led to enact such a measure.

Whilst upon the great subject of Australian geology, I cannot avoid touching on a *quæstio vexata* which has arisen in respect to the age of the coal-fields of that vast mass of land. Judging by the fossil plants from some of the Carboniferous deposits of Victoria, Prof. M'Coy has considered these coaly deposits to be of the Oolitic or Jurassic age, whilst the experienced geologist of New South Wales, the Rev. W. B. Clarke, seeing that, where he has examined these deposits, some of their plants are like those of the old coal, and that the beds repose conformably upon and pass down into strata with true Mountain-limestone fossils, holds the opinion that the coal is of palæozoic age. As Mr. Clarke, after citing a case where the coal-seams and plants were reached below Mountain-limestone fossils, expresses a hope that Mr. Gould may detect in Tasmania some data to aid in determining this question, I take this opportunity of stating that I will lay before this Meeting a communication I have just received from Mr. Gould, in which he says that in coal-fields of the rivers Mersey and Don (some of the very few which are worked in Tasmania), he has convinced himself that the coal underlies beds containing specimens of true old Carboniferous fossils. Remarking that these relations are so far unlike those which he observed on the eastern coast of the island, where the coal overlies, yet is conformable to, the Carboniferous limestone, he adds that in Tasmania, at least, the coal most worked is unquestionably of palæozoic age.

Now, as Australia is so vast a region, may not much of the coal within it be of the age assigned to it by Mr. Clarke; and yet, may not Prof. M'Coy be also right in assigning some of this mineral to the same oolitic age as the coal of Brora and the eastern moorlands of Yorkshire? In his survey of Tasmania, Mr. Gould has also made the important discovery of a resinous shale, termed Dysodile, and which, like the Torbane mineral of Scotland, promises to be turned to great account in the production of paraffine.

There are, indeed, other grounds for believing that coal, both of the Mesozoic as well as of the old Carboniferous age, may exist in Australia. Thus, putting aside the fossil evidences collected in Victoria by M'Coy and Selwyn, we learn, from the researches of Mr. Frank Gregory in Western Australia, that Mesozoic fossils (probably Cretaceous and Oolitic) occur in that region; whilst the Rev. W. B. Clarke informs me, in a letter just received, that he is in possession of a group of fossils transmitted from Queensland, 700 or 800 miles north of Sydney, which he is disposed to refer to the age of the Chalk, there being among the fossils *Belemnites, Pentacrinites, Pecten, Mytilus, Modiola*, &c. Again, the same persevering geologist has procured from New Zealand the remains of a fossil saurian, which, he thinks, is allied to the Plesiosaurus*.

It would therefore appear that in the southern hemisphere there is not merely a close analogy between the rocks of palæozoic age and our own, but further, that, as far as the Mesozoic formations have been developed, they also seem to be the equivalents of our typical secondary deposits.

This existence of groups of animals during the Silurian, Devonian, Carboniferous, and even in Mesozoic periods in Australia and New Zealand, similar to those which characterize these formations in Europe, is strongly in contrast with the state of nature which began to prevail there in the younger Tertiary period. We know from the writings of Owen that at that time the great continent at our antipodes was already characterized by the presence of those marsupial forms which still distinguish its *fauna* from that of any other part of the world.

In relation to our Australian colonies, I must also announce that I have recently been gratified in receiving from Messrs. Chambers and Finke, of Adelaide, a collection of the specimens collected by M'Douall Stuart in his celebrated traverse (the first one ever made) from South Australia to the watershed of North Australia. Having had occasion to address the Royal Geographical Society on this point, and to award its Gold Medal to that most adventurous and successful explorer, with observations on the main geographical results of his labours, including the discovery of trees and plants unknown in other parts of that continent, I may here say, in addressing myself to geologists, that a collection of rocks has been submitted to me which may tend to illustrate the structure of the interior of that great continent.

These specimens are soft, white, chalky rocks, with flints, agates, saline and ferruginous incrustations, tufas, breccias, and white quartz-rocks, and a few specimens of quasi-volcanic rock, but with scarce a fragment that can be referred to the older stages of Lower Silurian age like those of Victoria†. Again, the only fossil shells collected by Mr. Stuart (though the precise latitude and longitude are unknown to me) are Mytiloid and Mya-like forms, seemingly indicating a Tertiary age, and thus we may be disposed provisionally to infer that large tracts of the low interior between East and West Australia have in very recent geological periods been occupied by the sea.

Conclusion.—In concluding this Address, I may assure the Section that, as one of the original members of the Association, it gives me infinite satisfaction to return to my old friends in this great and thriving centre of our national industry. In common with many of my associates who come from a distance, well do I remember how cordially we were received here in the year 1842; and never can I forget how admirably we were presided over by a nobleman‡ as distinguished by his ability and learning as he was beloved for his philanthropy and public spirit, and who had upon his right hand the illustrious Dalton. Looking to the character and influence of that philosopher, I may truly say that, as he was one of our

* Whilst this is passing through the press, Professor Owen has described this interesting fossil, before this Section, as *Plesiosaurus Australis.*

† It must, however, be noted that the collection sent to me consists of small specimens of rock forming an imperfect series.

‡ Lord Francis Egerton, afterwards the Earl of Ellesmere.

founders when we first met together at York, we owe through him a deep debt of gratitude to Manchester; for Dalton was one of the few eminent men who at our birth stood sponsor for our future career, and who supported us at many a subsequent Meeting.

In our present visit we are most happy to see placed at our head one of the scientific men of Manchester, who exhibits in his own person the cheering example of the great success which can be attained by the steady and judicious application of science to the improvement of our manufactures. And if England is to hold her own lofty position in great measure through the superior strength of the metal derived from inexhaustible masses of iron-ore which occur in many of her geological formations, we cannot but regard William Fairbairn as the individual, who, united at first with the lamented Eaton Hodgkinson, through a long series of ingenious experiments, as detailed in the volumes of this Association, not only laid the basis for the erection of the Menai Bridge and such tubular constructions, but who is now directing the manufacture of those iron plates which may best resist the most powerful artillery, whether in casing our ships or in strengthening our fortresses.

I need not re-affirm that all the men of science who have flocked hither from distant places rejoice with his townsmen in serving under such a man.

Lastly let me say, that we of the Geological Section, who are gathered together from remote parts, have solid grounds for satisfaction in being greeted here by so many good and active brother workmen of the Geological Society of Manchester, who have done such honour to their town, not only by the establishment of a rich and instructive Museum, in which many of the subjects we are met to discuss are thoroughly illustrated, but who have also, by their publications, contributed much to advance our science.

Palæontological Remarks upon the Silurian Rocks of Ireland. *By* W. H. Baily, *F.G.S.*

In this paper the author noticed the occurrence of Llandeilo flags in the county of Meath, containing the characteristic Graptolite, *Didymograpsus Murchisonii*, and then proceeded to give a general review of the localities in Ireland from which fossils were obtained, as affording satisfactory evidence of the various subdivisions of the Silurian rocks at present ascertained in that country.

Remarks on the Bone-caves of Craven. *By* T. W. Barrow.

The author said that the specimens before the Meeting were found mainly in Victoria and Doukerbottom Caves, near Settle, Yorkshire. These caverns are but two of a great number which occur in the mountain limestone, and more especially in the Lower Scar limestone of Phillips. They are of various kinds—dry, wet, from a few yards in length to a mile, merely passages, or scooped out into great chambers. Doukerbottom consists of two chambers with very long passages between them. Victoria Cave, which was discovered by Mr. Jackson of Settle, has in it four large chambers close to each other, and before the flooring of clay was washed in, probably forming one gigantic apartment.

The general section of the caves is:—First, from a foot to 18 inches of soil, in which are the bones of recent and historic animals. Second, about 6 inches of the ancient flooring of the cave when it was inhabited by man: in this were found all the antiquities which were discovered, and the bones of animals similar to those last mentioned. Third, dense stiff clay of very great thickness, in which no antiquities and scarcely any bones were found. Fourth, the original rocky floor of the cave, resting on which were bones differing in colour, lightness, &c. from the others. The antiquities found in the second stratum were flint-implements, adze-head of stone, sling stones; of bone—arrowheads, combs and pins; shells and wolf's teeth pierced for a necklace. These were evidences that an uncivilized race had occupied the cave; but besides these were fibulæ, armlets and rings of bronze and iron, and coins of Roman emperors, from Nero to Constantine. The bones found were of recent and historic animals, such as the wild boar and the wolf; but with these were others of prehistoric animals, the cave-tiger and the cave-hyæna, found side by side with the antiquities; and it has been argued that they are therefore contemporaneous with man. The author, however, showed that their presence in such a position was accidental, and proved too much; for if these bones were contemporary with the antiquities, they were also contemporary with the coins, which come down to 400 A.D.—a time at which we are certain, from history, that there were no such animals in England. The present evidence from these caverns of man's contemporaneousness with such animals was not to be trusted.

A succinct account of the Geological Features of the neighbourhood of Manchester. *By* E. W. BINNEY, *F.R.S., F.G.S.*

The author described the several beds of gravel, sand, and clay forming the superficial covering of the district in the following (descending) order:—1st, The valley gravel, with its successive terraces, reaching to a thickness of 36 feet; 2nd, the widely-distributed upper sand and gravel, 135 feet; 3rd, the till, boulder- or brick-clay, 90 feet; 4th, the lower gravel and sand, 40 feet. The underlying rocks or skeleton of the country, known chiefly by boring operations, were then noticed:—1st, the pebble-bed of the Trias, about 600 feet thick. 2nd. The Permian series, consisting of marls containing beds of limestone and gypsum, about 300 feet in thickness; conglomerate, 25; and soft red sandstone, about 600 feet. These may be considered as the upper part of the Permian beds of Lancashire, but the equivalents of the lower series in Yorkshire. Below them come in soft red sandstones and beds of pebbly grit containing coal-plants, seen at Astley and Bedford, but not met with in the immediate vicinity of Manchester. The beds of conglomerate and soft red sandstone are found to thicken out northward in Lancashire, Westmoreland, Cumberland, and Scotland to several thousand feet in thickness. 3rd. The coal-measures of the Manchester coal-field, 1650 feet thick, as proved by sinkings and borings, and the few natural sections at Ardwick and elsewhere. All these strata are much dislocated, one fault being certainly a downthrow of 3150 feet at one point, and only 150 at another not many miles off. Some faults show evidence of great lateral motion. He regarded these faults as having been made for the most part immediately after the close of the Carboniferous era; they were further shifted before the deposition of the Trias, and no doubt had been frequently moved afterwards. The author illustrated his remarks by a geological map of the district, showing the distribution of the superficial clays, gravels, and sands; another map showing the arrangement of the lower rocks as far as yet determined; and by three sections of the district—one from Trinity Church, Hulme, to Waterhouses, another from the Exchange to Smedley, and the third from Eccles to Kersal Moor.

On the Extinct Volcanos of Australia. *By* J. BONWICK.

Having lately visited the extinct volcanos of Italy and France, as well as having observed the active cone of Vesuvius, the author did not think he was wrong in calling the south-western part of Victoria and the adjacent portion of South Australia the burnt fields of Australia. The country referred to lies chiefly between the slate and granite dividing range of the diggings and the tertiary limestone of the sea-coast, having an area of nearly half the size of England. It extends from the Bay of Port Phillip, near Melbourne, and Geelong, to beyond the western border of Victoria, by the Glenelg. The great basaltic plain of the west has few interruptions from the bay to the border and from the shore to the central range. The basalt is of all varieties, and furnishes in its decomposition the finest soil to the agriculturist. He had seen an island of basalt in a sea of slate, so to speak, which abounded with farms, though surrounded by heartless woods and shingle soil. Many dome-shaped lava hills are found on the plateau of the dividing range. Caverns, nearly 500 feet in length, exist in the basaltic floor of the plains. On the south-west side of the great salt lake Corangamite, there are basaltic rises. These are huge barriers from 10 to 60 feet in height, forming a vast labyrinth of rocks, 15 miles long by 12 broad. The natives in olden times retreated to these inaccessible retreats with the sheep they stole from the flocks in the neighbourhood. The ash or tufa has the same appearances as those the author observed at Lake Albano, near Rome, and at Pompeii. It is occasionally sufficiently solidified to become building-stone. Carvings are very commonly made of it in the district. The ash and cinder conglomerate exists but in one place—on the Island of Lawrence, in Portland Bay. Cliffs of this singular compound rise there 150 feet. The author's impression is that the source was a submarine volcano to the south-west,—the course of the prevailing wind and current; and that the ashes and volcanic dust were received in some sheltered bay, since raised with the coast. The extinct volcanos are in the form of lakes and mountains. The lakes are depressions usually on slight eminences. Terang, Elingamite, Purrumbete, Wangoon, and Lower Hill are fresh, while Keilambete and Bulleenmerri are salt. The shallow saline lakes of the plains were not former craters. The depths of some of these lakes are 50, 100, 150, 200, and 300 feet. The Devil's Inkstand of Mount Gambier is 260 feet. The banks vary from a few feet to 300 feet in height above the water. The circumference varies from 100 yards to 7 miles. The thickness of the ash increases with the distance from the crater, but is always thickest on the eastern side. At Lower Hill, at a quarter of a mile from the bank, on the northern quarter, it is 80 feet deep, while at a mile off, on the eastern side, it is 150 feet. The volcanic hills vary from a few yards to above 2000 feet above the sea-level. The depth of the dry craters runs from 50 feet to 300 feet. Gambier and Schanck are within the South Australian border. The former has three fine lakes. The latter is a dry basin, known as the Devil's Punchbowl. Porndon is a cone of very light cinder, elevated amidst the remarkable rises. Leura is a broken crater on the edge of the rises; while Purrumbete is a beautiful sheet of water, a few miles distant, which once, as a crater, discharged vast quantities of ash. The other principal volcanos of Western Victoria are Buninyong, Blowhard, Noorat, Gellibrand, Napier, Franklin, Cavern, Shadwell, Lower Hill, Clay, Elephant, Eckersley. No adequate impression can be received as to the age of the activity of these cones and craters. There is a freshness in most of them indicative of a comparatively modern date. The natives have traditions of the eruptions of several of them. As loam overspreads the recently scattered auriferous drift of several of the diggings, it would not appear to have been of great date. It occurs on tertiary limestone to the west, and underlies it as well.

Mr. Antonio Brady exhibited some flint instruments, together with bones of *Elephas primigenius* and *Echini*, obtained by him only a few days since from the drift at St. Acheul, near Amiens. He stated that although found only a few feet above the chalk, in the drift, in true association with the bones and shells of extinct species, still, from the composition of the drift, there was in his judgment no proof that the animals and the makers of the instruments lived at one and the same time. From the heterogeneous and rolled state of the materials, there was great reason to believe that they had been disinterred from their original resting-places by some sudden torrent or convulsion, and been reinterred in their present association. The drift had clearly never been lifted by the hand of man, but is doubtless in the state in which it was deposited, whenever that may have been.

On the Aqueous Origin of Granite. *By* Alexander Bryson, *F.R.S.E., P.R.S.S.A.*

In this paper the author referred to the labours of Dr. William Smith, who published his 'Tabular View of the British Strata' in 1790, and remarked that since that period geology had been studied mainly in the direction of palæontology. Physical, chemical, and dynamic geology were left almost unregarded by the great masters of the science, who generally accepted the speculations of Hutton and the experiments of Hall as demonstrating the igneous origin of the primary rocks.

The author stated that the Huttonian theory was most ably attacked, and, in his opinion, overthrown, by Dr. Murray in his 'Comparative View of the Huttonian and Neptunian Systems of Geology,' a work most unaccountably overlooked. Since that time it had suggested itself to the sagacious mind of Davy, that the occurrence of fluids in the cavities of crystals seemed to point to an aqueous origin. He also alluded to the writings of Brewster, Sivewright, and Nicol in the same field; also to Becquerel, Fuchs, Bischoff, and Delesse, who have taken up the subject of the aqueous origin of rocks from a chemical point of view. The author then laid before the Society the result of ten years' experimental investigation into the structure of rocks relative to their formation, more particularly granite. While examining microscopically the various pitchstone veins abounding in Arran, he was much struck with the similarity of their structure, and the marked difference they exhibited when compared with sections of granite and its various mineral constituents. On extending his observations to obsidian, marekanite (a volcanic glass from Lake Marekan in Kamtschatka), and also to the well-known glassy obsidian of Bohemia, he found they all exhibited a structure analogous to the pitchstones of Arran. He further found that sections of glass slags, where the heat had been long continued, combined with slow cooling, all presented the same appearances as the sections of pitchstone.

This structure, peculiar to igneously formed substances, he found usually to radiate in a stellate form; and though many slags showed large stars visible to the naked eye, the stellate structure is more easily observed by the aid of the microscope. The character is so marked, that no one whose eye is tutored to microscopic observation can fail to recognize at once a mineral substance of igneous origin.

In granite, on the other hand, the structure, as seen by the microscope, is as persistent as in pitchstone, glass, and obsidian, but totally different.

In the many experiments which the author had tried with granites from various localities, he had never succeeded in obtaining one instance of stellate structure, while the constant occurrence of cavities containing fluids convinced him that, if pitchstone and glass are types of igneous-formed substances, granite must be of aqueous origin. In the fluid cavities so abundant in topaz, Cairngorum, beryl, tourmaline, and felspar, all constituents of granite, he found the same appearance prevailed. These cavities are seldom entirely filled with fluid, an air-bubble usually occupying more or less of the cavity. After many hundred experiments on such cavities, the author found that when exposed to a temperature of 94° Fahr., the bubble disappeared, the fluid entirely filling the cavity, and at the temperature of 84° the bubble reappeared with a singular ebullition, showing that the air had formed an atmosphere round the fluid. He was thus led to infer that these cavities could not have been filled at a temperature above 84°, and certainly not above 94° of Fahrenheit.

As another proof that these cavities could not have been filled when the temperature of the surrounding rock was higher than the temperature above indicated, the author drew attention to the fact that the bubble of air occupied always a much smaller portion of the cavity than the fluid, a condition which could not obtain, if, as other writers hold, the fluids were enclosed under intense heat and pressure.

For the purpose of accurately determining the temperatures at which the bubble vanished and reappeared, the author constructed an apparatus which he exhibited and described. It consists of a microscope with a hollow iron stage, having a tube in the centre to admit light from the reflector. At one side, and inserted into the stage, is a small tin retort with a stopper; at the other side, a tube is inserted and attached to a reservoir of water, from which the hollow stage and retort are filled. On applying heat to the retort by means of a spirit-lamp, any required temperature under the boiling-point of the water may be obtained in the stage and retort.

Above the stage is placed an iron saucer, in the centre of which an iron tube is riveted, through which the light is admitted; this vessel is filled with mercury, and in it is placed an upright thermometer, with the bulb shielded with cork or any other good non-conductor; by this means it indicates the actual temperature of the mercury bath. The cavity to be observed is cemented with Canada balsam to a plate of glass 3×1 inch, and is floated on the surface of the mercury, so that the glass and mercury are in absolute contact. When the temperature is raised until the bubble nearly disappears (which is seen by its contraction), the spirit-lamp is withdrawn, and the vanishing point carefully watched and the temperature noted. The stopper of the retort is then withdrawn, and the stopcock of the reservoir of water opened, so that the temperature of the stage and mercury bath is soon reduced, and the ebullition or reappearance of the bubble takes place, when the temperature is again recorded. By this method the author felt confident that his results were correct, as they always were consistent when observing the same cavity. By means of this instrument the author had found fluid cavities in the trap tuff of Arthur's Seat, the greenstone of the Crags, and the basalt of Samson's Ribs. He had also found that the porphyry of Dun Dhu in Arran, which most geologists assumed as of igneous origin, was full of fluid cavities contained in the doubly acuminated crystals of quartz for which this remarkable porphyry is distinguished. He also showed doubly acuminated crystals of quartz in the saliferous gypsums of India, both of which were full of fluid cavities, and the quartz impressed with the gypsum; and as no geologist would hold that this formation was of igneous origin, but that the quartz, if not contemporaneous with the gypsum, must have been subsequent, and as the same phenomena were presented by the porphyry of Dun Dhu, he was forced to the conclusion that it was as much aqueous in its origin as the saliferous gypsum of India. The author exhibited a specimen of quartz which contained a crystal of iron pyrites, to which was attached a crystal of galena and also a small massy zinc blende, while over these three metals was laid a covering of gold. From this specimen he argued, that as all these metals were fusible at a much lower temperature than quartz, they must have aggregated during a gelatinous condition of the quartz; and further, that as the sulphides of the three metals were in chemically combining proportions, any heat which would have fused the quartz would have made an alloy or a slag in which chemical combining proportions could not occur.

He also exhibited specimens of schorl which he had obtained in the granite of Aberdeen, and drew the inference that schorl, which crackles and splits with a very small increment of temperature, could not have been present during a molten condition of the quartz; and that it was crystallized prior to the solidifying of the latter, as proved by the schorl impressing the quartz. The author, from a careful examination of the schorls in the quartzite of Aberdeen, was led to believe that the quartz, while in the process of crystallization, expanded one twenty-fourth of its bulk, a force which appeared to him to be sufficient to cause all the upheavals and disruptions which had led geologists to account for such phenomena by a molten condition of the primary rocks. If this view is correct, and if the highest peak is granite, as the lowest is known to be granite, the author calculated that as the highest mountain is only $\frac{1}{571}$ part of the radius of the earth, a thickness of the crust of 168 miles is quite sufficient to yield expansive force to raise the highest peak of the Himalayan range. He further stated that the cause of the temperature at which the fluids were confined being higher than the normal one, depended on the rise of temperature which takes place during solidification.

The author, in conclusion, trusted he would soon be in a position to confirm these views when he had finished the investigation of the trap-rocks with which he is now engaged.

On the Laws discoverable as to the Formation of Land on the Globe. *By the* Rev. C. R. Gordon.

Results of the Geological Survey of Tasmania. *By* C. Gould, *B.A., F.G.S.*

The formations treated of were the upper palæozoic marine deposits and the coal-measures. The apparent conformability of the two sections was shown, together with their intimate connexion, serving to render their consideration inseparable. The coal-measures exist to a greater or less extent throughout the country referred to, the depth being about 900 feet. The coal-measures of the district might be regarded as constituting two distinct fields, the maximum one of which might be termed the Mount Nicholas Coal-field, comprehending the various portions developed upon either side of the Break o' Day Valley, while to the other the term Douglas River Coal-field might be applied, as indicating the area occupied by the carboniferous formation between Long Point and Bicheno. In the first the position of the principal seams of coal, although highly advantageous to their being worked, is at an elevation of from 1200 to 1500 feet above the sea. There were at least six distinct seams in the Mount Nicholas coal-field, one of which was of superior quality, and 12 feet in thickness. Ever since the discovery of the seam experiments have been made, which, though amply sufficient to prove the value of the coal for domestic purposes and for application to the usual branches of manufacture, have been upon too limited a scale to permit of the determination of its value as a steam fuel. A remarkable shale exists in the north of the island, available as a source of paraffine and paraffine oil. The Mersey coal-field was one of the very few in Tasmania which are actually worked; for although the extent of coal throughout the island is almost unlimited, there are very few points at which any operations are conducted.

On the Faults of a portion of the Lancashire Coal-field.
By A. H. Green, *M.A., of the Geological Survey of Great Britain.*

In this paper a law was enunciated which appeared to govern the directions of the principal lines of fault in the portion of the Lancashire coal-field lying between the meridians of Wigan on the west and Rochdale on the east.

On the western side of this tract the average direction of the faults is about 20° W. of N.; as we go eastwards the lines of fracture tend more and more towards an E. and W. direction, till in the neighbourhood of Rochdale they are found to run from 45° to 50° W. of N.

An attempt was made to show, on the principles laid down by Mr. Hopkins in the sixth volume of the Cambridge Philosophical Transactions, that this law was a necessary consequence of the elevating forces which produced the upheaval of the coal-field.

The upheaving forces seem to have exerted their greatest force along the northern and eastern boundaries, increasing in each case towards the north-east corner; the western boundary seems to have been a line of upheaval of smaller and more uniform intensity; and on the south, where the coal-measures pass below the new red sandstone, the force of upheaval has decreased to a minimum.

Hence it was inferred that the southern and western boundaries of the coal-field might be considered as remaining undisturbed during the upheaval, while its north-eastern corner had been elevated. The extension of the strata produced by this upheaval, as soon as it exceeded their power of cohesion, would cause fissures; and the directions of these fissures, indicated by theory, coincide very nearly with the observed lines of the principal faults.

Comparison of Fossil Insects of England and Bavaria. By Dr. Hagen.
(Communicated by H. T. Stainton, *F.L.S.)*

The author remarked that formerly the fossiliferous strata of Solenhofen and Eichstadt in Bavaria had been considered analogous to the English secondary strata, but that later investigations had established that the latter were considerably older. "I must especially call attention to the fact, that the species described by Germar in the 'Acta Academiæ Leopold,' to which hitherto reference has always been made, are described from specimens the outline of which has been artistically painted and completed. I have often examined the types carefully, and can maintain with certainty that this account of them is correct. The Royal Collection in the Academy of Munich, and the collection of Dr. Crantz in Bonn, contain together about 1000 stones with insects, and, even deducting the double stones, thus represent at least 600 specimens.

"Having an opportunity a few weeks back of studying very carefully the Munich collection, I was much surprised at the splendid preservation of many of the specimens. The insects of the Solenhofen strata are almost universally preserved entire; wings, legs, head, and antennæ are in their proper places; most of the *Libellulæ* have their wings expanded. He who, on the sandy shores of the Baltic, has noticed how depositions of insects are now taking place, will admit that these Solenhofen insects must have been dead when deposited. They would be driven by the winds into the sea, thrown on the shore dead or dying, and then gradually covered with sand by the rippling waves. This process took place on the Solenhofen strata extremely gradually and slowly, as is evident from another circumstance; for we frequently find the cavities of insects (the head, thorax, and body) filled up with regular crystals of calcareous spar. Hence the pressure of the stratum overlying the insect must have been very slight, when such delicate parts as the abdominal segments of a dragon-fly could oppose resistance for a sufficient length of time to admit of the formation of crystals.

"The English strata, on the other hand, rarely contain entire insects; generally there are only some part of the wings, abdomen, and thorax, and these besides are usually imperfect. Hence it appears worthy of consideration whether the insects of the English strata do not convey the inference that, through the agency of storms and other commotions, the fragments were tossed about a long time before they found a resting-place.

"There is the less to be said against this conjecture, as the wings of insects (which form by far the larger part of the English entomological fossils) are almost indestructible in water. I have kept the wings of dragon-flies in water for years without observing the slightest change in their texture.

"From a careful study of the fossils of Solenhofen, and a comparison with the published figures of the fossil insects of England, I have deduced two conclusions:—

"First, that the two faunæ are very closely allied, and possibly some species in both formations are identical.

"Secondly, that the faunæ of Solenhofen and of the English strata are not only quite distinct from the existing fauna, but also from those of Aix, of the Rhenish peat-deposit of Œningen and Radoboj, and from that of amber, differing not only in species but in genera.

"Almost all the Solenhofen insects will necessitate the construction of new genera, which, however, will often furnish connecting links between some of our existing genera.

"In reference to the *Odonata* (dragon-flies), which form so large a portion of the insect fauna of the Solenhofen strata, and pieces of the wings of which seem not uncommon in the English strata, we find a remarkable contrast between the fauna of the English secondary strata and the fauna of Œningen and Radoboj. Whereas here, as also in the Rhenish peat, larvæ and pupæ of *Libellulæ* are found in great numbers, many often lying together, the perfect insects being proportionally scarce; in the Solenhofen and Eichstadt deposits *Libellulæ* are precisely the most plentiful specimens (forming $\frac{1}{3}$rd of all the insects), and on the other hand, up to the present time not a single larva or pupa has been found.

"The absence of larvæ in the Solenhofen strata may be accounted for by the supposition that the waters on whose shores these strata were deposited were salt; just as at the present day numerous *Odonata* are buried in the sands on the shores of the Baltic, although their larvæ do not live in that sea. The deposits of Œningen and Radoboj, on the other hand, we must conclude were made in fresh water."

On the Old Red Sandstone of South Perthshire. *By* Professor Harkness, *F.R.S., F.G.S.*

At the Bridge of Allan, which is situated immediately on the north side of the fault separating the coal-field of Stirlingshire from the Old Red Sandstones on the north thereof, there are seen, on the side of the hill near the well, conglomerates which are principally made up of fragments of trap, and these, in their higher beds, have grey sandstones intercalated with them. These grey sandstones, on ascending the series, occur exclusively; and they are well seen at Wolf's Hole quarry, dipping at 20° N.W., being capped by trap. Here, in the grey sandstones, the remains of *Pteraspis rostratus* have been found, and in the same strata portions of a *Cephalaspis* also occur.

A section showing the arrangement of the deposits which succeed these grey sandstones may be seen in the course of the Allan to beyond Dumblane. A continuation of this section may be obtained in the course of the Teith; and the river Keltie, which flows into the Teith about 3 miles below Callander, furnishes the series of deposits which join those of the Teith. Collectively a section may be had showing the nature and the arrangement of the deposits which occupy the area between the fault alluded to as occurring on the south, and the metamorphic rocks of the southern flanks of the Grampians.

This section exhibits a trough on the margins of which conglomerates occur, these forming the lowest strata.

To these conglomerates succeed deposits which contain *Pteraspis* and *Cephalaspis*, consisting of grey sandstones. Purple strata occur above these, to which succeed reddish shaly beds; and, on the S.E. side of the section, brown sandstones are found upon the shales, while on the N.W. side these brown sandstones contain also quartz conglomerates. Upon this portion of the series grey flaggy sandstones are seen, and these form the highest members of the rocky strata observable in this portion of Scotland.

The total thickness of the deposits which this section exhibits exceeds 7000 feet, and it is interesting not only as showing the position of the Pteraspis beds, but also as indicating an area south of the Grampians where, underneath the Forfarshire flags, a thick mass of conglomerate forms the lowest members of the Old Red Sandstone formation.

**On the Sandstones and their associated Deposits of the Valley of the Eden and the Cumberland Plain. By* Professor Harkness, *F.R.S., F.G.S.*

In the valley of the Eden, from a short distance south of Kirkby Stephen northward, there occur extensive developments of sandstone, which, in many localities south of Appleby, have beds of breccia associated with them. These sandstones, having usually a nearly eastern dip, are spread over the western portion of the Vale of the Eden in Cumberland, and have as their western boundaries the Carboniferous series. In Cumberland they attain a great thickness, probably nearly 5000 feet. They possess the same mineral nature as the sandstones which in Dumfriesshire afford footprints; and Ichnolites of a like character to those of the south of Scotland have been found in some localities in these Cumberland deposits. They are usually succeeded conformably by clays of a red colour. In some areas these clays contain gypsum; and at one spot, near the village of Hilton in Westmoreland, there is seen, between the sandstones and breccias below and the clay-beds above, a thin series of deposits which vary much in their lithology. The lower portion of these has a character approaching that of the marl-slate of Durham, and from this fossils are obtained, principally in the form of coniferous leaves. Casts of small crinoid stems are also seen, and likewise casts of Brachiopods and Lamellibranchiates. The *facies* which these fossils present, induces the conclusion that the strata which contain them represent here the marl-slate. Under these circumstances the succeeding marls and gypsum must be looked upon as appertaining to the Zechstein portion of the Permians, while the underlying red sandstones and breccias must be regarded as the equivalent of the German Rothliegende, which in this portion of England have a very great development, and which, as they contain the footprints before alluded to, place the Permians of Dumfriesshire that afford Ichnolites among the lowest group of this formation.

The clay-beds which represent the Zechstein are conformably succeeded by fine-grained red sandstones with clay layers. These abound in ripple-marks, desiccation-cracks, rain-pittings, and pseudomorphs, features which are never found in connexion with the inferior sandstones. These upper sandstones seem rather to belong to the Trias than the Permians. They trough under the Solway Firth, being well developed in the S.E. of Dumfriesshire; and they appear to support the lias, as this has been described as occurring in the north of Cumberland by Mr. Binney.

Notice of Elongated Ridges of Drift, common in the South of Scotland, called 'Kaims.' By D. Milne Home, *F.R.S.E.*

The author described a number of examples of them in Berwickshire, Roxburghshire, and other places. He stated that they were so regular as to have the appearance of railway embankments or fortifications, and that they had often been mistaken for the latter. They were from 40 feet to 60 feet in height, and sometimes could be traced for three or four miles. They were found at various heights above the sea up to 750 feet. In examining their internal structure, they were seen to consist generally of sand, gravel, and boulders; the latter generally rounded, but also occasionally angular. He adverted to the fact that they are sometimes intersected by rivulets and even rivers, but that notwithstanding this, they had all the appearance of having, when originally formed, been continuous. The author offered some remarks on the agency supposed to have been concerned in the production of the kaims. He repudiated the notion of their formation by glaciers. He considered they were due to the action of water, as indicated by their internal structure; and supposed that they must have been formed by the waters of the ocean, when they stood at least 800 feet above its present level. The only question, as he thought, was, whether they had been thrown up as submarine spits or banks, or whether they had been formed by a process of scooping-out, when the land emerged from the ocean. His opinion wavered between these two views; but he was inclined to the former. In the east of Scotland, these kaims had mostly one direction, viz. east and west; and as they were in various positions, sometimes on level land and sometimes on sloping hills, he thought that a sudden lift of the country out of the ocean would better produce that uniformity of direction than any other view, and also occasion the scooping-out and removal of materials, leaving continuous ridges.

On Isomeric Lines, and the relative Distribution of the Calcareous and Sedimentary Strata of the Carboniferous Group of Britain. By EDWARD HULL, *B.A., F.G.S., of the Geological Survey of Great Britain.*

The author referred to the observations of Prof. Phillips in Yorkshire in reference to the carboniferous rocks, from which it appeared that the calcareous portions attained their greatest vertical development towards the south-east, while the sedimentary strata of the Yoredale series and millstone grit increased in thickness towards the north-west; and the author went on to show that what was true in Yorkshire on a smaller scale, was also true on a larger scale for the whole of the carboniferous rocks north of the old barrier of land which stretched across Central England during the Carboniferous epoch.

It was shown that the carboniferous limestone was most fully developed in Derbyshire, attaining a thickness of about 5000 feet, and from this as a centre it thinned away westward and northward, so that in Scotland the thickness was only about 250 feet, in some places even less than this.

On the other hand, it was shown that the sedimentary strata (sandstones, shales, &c.) were of greatest thickness in Lancashire, and from this thinned away eastward, southward, and partially westward. The thickness of these strata in Lancashire (12,500 feet) had probably once been exceeded in Scotland, where, reasoning from analogy, Mr. Hull concluded the whole carboniferous group, excluding the limestones, had once reached 14,000 feet, previous to the denudation which has swept away the uppermost members of the coal-measures*.

These variations in thickness of the sedimentary strata were indicated by the isometric lines on the maps exhibited to the Section, and are accounted for on the ground that, throughout the Carboniferous period, a large tract of land had existed in the North Atlantic, from which the sediment had been derived and spread over the bed of the sea by a current coming from the north-west. In consequence of this, the sands and clays would gradually lessen in quantity the further they were carried, and thus they would be deposited in greatest force towards the north-west, and in least towards the south-east, where there would be a clear sea.

On the other hand, the limestones, being due to the labours of marine animals which required an ocean free from mud for their full development, were formed in greatest force in Derbyshire, and from this as a centre diminish in thickness westward and northward. Thus in Scotland they are on the point of disappearing, being replaced by a vast thickness of sedimentary strata altogether wanting in Central England. These variations were indicated by a second system of isometric lines, indicating the propagation of the calcareous rocks from Derbyshire as a centre in a series of waves of constantly diminishing force. It would thus be seen that the two sets of isometric lines above referred to would intersect each other from nearly opposite directions.

To account for these opposite developments, the author showed that they arose from the necessity of things; that the marine animals (as the corals and crinoids),

* These results were borne out by admeasurements of the beds in several counties, which are published at length in the Journal of the Geological Society of London, vol. xviii. p. 127.

of whose labours mainly the limestones are the result, required a pure ocean uncontaminated by sediment. This was the case with the ocean in Derbyshire; but in the north it was charged with sand and mud, which interfered with, and ultimately overpowered the organic agents. Hence the essential distinction between limestones and all other kinds of sedimentary strata was strongly insisted upon, the one being directly antagonistic to the other.

The author next showed that we could trace at intervals the north and south coasts of a barrier of land which stretched from Wales to the German Ocean during the Carboniferous period. (See Map, Journ. Geol. Soc. vol. xviii.)

South of this barrier there exists another carboniferous tract, represented by the coal-fields of South Wales, Somersetshire, Gloucestershire, and possibly of one underlying the cretaceous rocks and stretching into Belgium. This tract was separated by the barrier from that of Central England, and the sediment had been carried from a different direction. The isometric lines, drawn in accordance with the variations of thickness as described by Sir H. De la Beche, showed that the sediment had been carried by a current coming from the W.S.W., while the calcareous group had been propagated in greatest abundance from the east; so that on the south side of the barrier there was as great a contrast in the distribution of the calcareous and sedimentary strata as on the north side.

The author next proceeded to remark that America exhibited phenomena of a kind similar to those here described in Britain. As had been shown by Sir C. Lyell and Prof. Rogers, the sedimentary strata augmented towards the N.E. in Nova Scotia, and became attenuated in the basin of the Mississippi (in which direction the limestones increase in vertical dimensions), proving that the sediment had been drifted from the north-east. The author contended that the same great continent of the North Atlantic had been the progenitor of the carboniferous strata of both America and Britain, and that its shores were swept by a north-east current in the western hemisphere, and by a north-west current in the eastern.

On the Progress of the Survey in Ireland.
By Professor Jukes, *F.G.S., Local Superintendent of the Irish Survey.*

On the Relation of the Eskdale Granite at Bootle to the Schistose Rocks, with Remarks on the General Metamorphic Origin of Granite. By J. G. Marshall, *F.G.S.*

In a paper read by me at the Meeting of the British Association at Leeds in 1858, on the Geology of the Lake District, I endeavoured to establish the following propositions:—

1. That the older slate rocks of Cumberland and Westmoreland, the Skiddaw clay-slate, and the greenstone slate series, have been generally subject to the metamorphic action of heat, pressure, and moisture.

2. That some of the slaty beds being more fusible than others above or below them in the series, have been more acted on than the less fusible beds, and changed into porphyries, whilst the others have only been hardened; and hence an alternation of stratified and unstratified beds has resulted, though the whole series were originally soft stratified deposits.

3. That the granites and syenites of this district are as truly metamorphic rocks as the porphyries—the change to the crystalline structure being merely the last term, the extreme result of the metamorphic action of combined heat, pressure, and moisture, followed by very slow cooling; and that these rocks, when found in mass, are not eruptive or intrusive, but altered beds of slate rock *in situ* in their natural position as regards other beds in the series.

4. That the forces which have elevated, contorted, and fractured the strata of this district have not been the eruptive energies of the granites and syenites, but have been produced by the expansion or contraction of the earth's crust, by heating or cooling on a large scale, and chiefly shown in great *lateral thrusts*, producing flexures and fractures in the weaker portions of the crust of the earth.

The metamorphic rocks in the vicinity of Bootle, under Black Comb, have been noticed by Sedgwick, and also by Phillips, as offering many remarkable phenomena; and as the granite was not considered by either of these observers as a metamorphic rock, I have been induced to pay another short visit to the locality in order to examine especially the evidence for or against that supposition.

The first point which I examined was the appearance of granitic rock in the course of a branch of the stream which runs through Bootle from Black Comb, and called Hole Gill. This rock first appears in a quarry near the entrance of the ravine through which the stream descends Black Comb. It is seen in three places—two on the southern side and one on the northern side, and all near the bottom of the ravine and within a distance of 300 or 400 yards. This rock (specimens Nos. 1 & 2), though of a felspathic and granitic character, is far from being a perfectly formed granite, and appeared to me to be quite analogous to the transition beds so constantly observed in the slaty rocks when the metamorphic change is just commencing. Moreover, in the spot where this rock appears on the northern side of the ravine, it is seen distinctly dipping conformably under the soft clay-slate, at an angle of about 25° or 30° to N.W.

I am of course familiar with the syenitic dykes which so frequently occur in this district, and have followed several of them for miles; but I could see no appearance of vertical or unconformable position in these granitic rocks in Hole Gill to indicate that they were dykes or elvans. They had rather the appearance of beds of the clay-slate in which the metamorphic action was commencing; and they appear at the very base of Black Comb, and nearly on a level with the adjacent metamorphic rocks of the greenstone slate formation.

The next appearance of metamorphic action is at a distance of about half a mile northward from the ravine just mentioned, in a range of slate rock which in the distance of 300 or 400 yards is gradually and completely changed from a perfectly fissile and unaltered slate at the southern end to a compact massive greenstone and porphyry at the other or northern end (Nos. 3–8 specimens), where it is intersected by another branch of the Bootle stream. It would be impossible to find a more perfect example than this ridge of rock affords of gradual metamorphic change along the line of strike. Between this second branch of the stream and a third branch, about half a mile further north, there is a broken hillocky ridge of metamorphic slate changed into hard greenstone and porphyry, and the beds much tossed about and dislocated (specimens 9–11).

The third branch of the stream intersects the border of the granitic range of rocks, which from this point extend continuously to the Esk and up Eskdale.

When first seen *in situ* the granite is very soft, incoherent, and disintegrating so as to be little more than granitic sand, and yet in the faces of the escarpment formed by the stream in this soft mass all the marks of stratification and jointing of the original slate rocks, of which it appears to have been formed, are distinctly visible. This granite is hornblendic, and shows the nodular and concretionary structure. A little further north, in a plateau or moderately elevated ridge, the granitic rock appears in a hard and solid state; the forms of the blocks, however, when in mass *in situ*, still preserving the angular and prismatic forms of the adjacent greenstone and porphyry beds, and with the same dislocated and broken appearance.

I could not anywhere see any distinct junction of the granite with the greenstone and porphyry rocks; nor did I observe veins or dykes proceeding from the granite, though possibly a longer search might have been more successful.

The general result of the series of phenomena appeared to me to be the indication of a gradually increasing intensity of metamorphic action in proceeding north or north-westward in the direction of the general dip of the strata. The granitic rocks appeared in the position in which the lower beds of the greenstone slate would naturally be found, and there was no disturbance of a nature that would indicate the intrusion of the granite amongst beds previously formed.

It is quite true that there is dislocation and fracture of the beds, both of the granitic and porphyritic rocks. But a dislocation exactly similar occurs in the same beds of greenstone slate on the other or eastern flank of Black Comb, where there is no granite. In both cases this dislocation of the beds seems to be produced by the wrapping of hard and rigid strata round the central mass of Black Comb. This formation alone would necessarily dislocate and fracture the beds of rock as we now see them.

It appears therefore that the phenomena observed in the metamorphic and granitic rocks near Bootle may be accounted for without supposing the granitic rocks to have been intrusive, or attributing the metamorphic action in the slate rocks to the agency of the granite.

We may consider Eskdale and Miterdale, taken together, to be a broad synclinal valley formed of the beds of the greenstone slate formation; that the beds now forming the lower or central portion of that valley were the lowest beds of the series, and were once covered up by a great thickness of the higher beds of this formation, such as now form Sca Fell and other neighbouring mountains, and were consequently exposed to metamorphic action and converted into granite. The superincumbent strata being afterwards denuded, the granite beds appeared on the surface as we now see them. On this explanation we must, of course, suppose the anticlinal ridge of Black Comb, as well as the synclinal valley of Eskdale and Miterdale, to have been formed before the metamorphic action took place, and that hence the beds of rock in that ridge, and in the other boundaries of Eskdale above the level of the granite, were not buried sufficiently deep below the former surface to be strongly acted upon by the central heat.

I may now perhaps venture to offer a few remarks and reasons in support of the opinion that there exist no sufficient grounds for separating granites, syenites, and other crystalline unstratified rocks generally, from the class of metamorphic rocks. I by no means wish to assert that there may not exist in certain localities true primeval granite—portions of the original and first-formed crust of the earth, or that granite is not in innumerable instances an intrusive or eruptive rock *in a certain sense, and within certain limits.* It may be impossible to prove the negative of the first supposition; the second is undoubtedly true. But I am not called upon to dispute either of these suppositions—both are compatible with the opinion I am supporting. For I think it is evident that we cannot suppose granite to exist in a fluid state underneath solid strata full of cracks, fissures, and fractures, and not perceive that, as a necessary consequence of its fluidity merely, the granite must penetrate and fill these cracks and fissures, and must have broken fragments or masses imbedded in its substance.

In this penetration of solid strata by fluid granite, the granite may be perfectly passive. If true and constantly acting causes can be shown to exist, which must throw the solid crust of the earth into flexures and contortions, and produce fractures, cracks, and fissures, we have an explanation of the whole of the phenomena without supposing the granite to be in any way an active agent.

It may be objected that we see fluid lava forced up to high levels and poured out from the sides of volcanos; and why may not granite at former periods have been subject to similar volcanic forces? Let us consider what are the necessary conditions of a volcanic eruption of lava. One invariable condition is the presence and violent liberation of vast volumes of highly compressed vapours or gases, which are evidently the active forces which drive up the lava and eject stones and ashes. Volcanos are situated on deep fissures in the earth's crust, which admit air and water occasionally to great depths, where, being enclosed by accumulations from above and gradually and highly heated, their elastic tension at last is sufficient to force up fluid lava with which they may be in contact, or to blow out the obstructing materials which confine them in the shape of an eruption of stones and ashes.

But all these phenomena are local, and limited in extent; the elastic vapours cannot act explosively unless they are entirely enclosed within the walls of solid strata, which afford the necessary resistance, and act indeed in the same manner as the sides of a closed vessel would do. There is no evidence accordingly that volcanic vents pierce so deep as the seas of fluid granite which lie entirely under the solid crust of the earth. And if elastic vapours do exist in these subterranean oceans of fluid rock, as no confining walls can there exist, their pressure will be distributed equally in all directions and over large spaces, and there will be no tendency to force up fluid rock in one place rather than another. There is then, I think, a clear distinction between the intrusion of granite veins into surrounding rocks, produced merely by the weight of the superincumbent solid rocks forcing the granite into whatever cracks and fissures exist in them, and the forcible ejection of lava from volcanos.

If it should be conceded that there is no evidence that granites are eruptive rocks, except passively as I have described—that there is no reason to attribute to them any active energy or force in elevating strata or raising mountain-chains, for the production of which effects we see other quite distinct and sufficient causes at work, it only remains to inquire whether there is any reason to doubt the sufficiency of the metamorphic action of heat, pressure, and moisture, followed by slow cooling, to produce granites and syenites, as well as gneiss, quartz, and mica-schist, out of sedimentary rocks;—whether granites, speaking generally and on a broad scale, are not true metamorphic rocks *in situ* in their natural position as regards other strata.

For a reply to this inquiry, I would confidently appeal to the great strides lately made in the geology of primitive districts, such as the whole of the north of Scotland, in proving that the strata until lately of unknown origin, in vast districts, are, as proved by Sir R. Murchison, our old acquaintance, the sedimentary rocks of the Silurian system in a metamorphic state. And when we see these metamorphic rocks running by insensible gradation in a thousand ways into granites, and inextricably mixed up with them, the positive evidence is strong indeed that the origin of all these rocks is similar; and I think there is no negative evidence against this supposition. On the contrary, I think the remarkable progress making in the study of the formation of minerals and rocks under the joint influence of heat, pressure, and moisture, followed by slow cooling, the true metamorphic condition, is all favourable to the position that granites and all similar crystalline rocks are generally to be classed as the last term of metamorphism.

I am fully sensible that the slight amount of subject-matter of observation, or details of evidence contained in such a paper as this, make it of little more value than as a sort of pioneer in the field of inquiry—the suggestion of conclusions which can only be verified or disproved by evidence of varied character, and by much more extensive observations than I have been able to adduce. I shall be satisfied if it may in any way contribute to more valuable and conclusive investigation.

On the Pleistocene Deposits of the District around Liverpool. *By* George H. Morton, *F.G.S.*

The author divides all the superficial accumulations of the district into the following subdivisions:—

Pleistocene deposits.	*Post-Glacial.* Average thickness 10 feet.	Drift sand. Bluish silt. Submarine forests.
	Glacial. Average thickness 100 feet.	Upper drift sand. Boulder clay. Lower drift sand.

The *Lower drift sand* is generally beneath the boulder clay where the latter is of any considerable thickness. It is seen to advantage in the cliffs on the shores of the Mersey, exhibiting nests or patches of gravel. There are shells: *Turritella communis* is common; *Nassa reticulata, Nucula oblonga*; fragments of *Natica, Patella,* and *Tellina* also occur.

The *Boulder clay* is the dark-red clay extensively used for brick-making. It contains numerous pebbles and boulders, which vary in size from that of a pea to immense blocks six feet in diameter, many of them being striated and grooved by ice-action. They consist of quartz, granite, syenite, porphyry, greenstone, basalt, slate, limestone, and, rarely, of new red sandstone. The shell *Turritella communis* is common, as in the underlying sands. *Mactra truncata* also occurs, with fragments of undetermined species.

The *Upper drift sand* is of limited extent, but is well developed at the south-east the town. No trace of shells nor any pebbles have been found.

Post-glacial deposits.—These are evidently of later age than those inland deposits such as at Leeds and Oxford, for no trace of the Elephant has been found. The only mammalian remains discovered, in addition to those now living in the neighbourhood, belong to *Bos primigenius, Bos longifrons*, and *Cervus elaphus*. Skulls, horns, and bones of these animals have been found in silt, associated with several submarine forest beds, which occur at various depths in different places in the neighbourhood. A section at the North Docks shows a submarine forest bed resting on the rock, at the depth of 35 feet below the high-water level of a 20-feet spring tide. A section beneath the Custom-house shows a similar bed with the trunks of trees 29 feet, and another 40 feet, below a tide of the same height. A section across Wallasey Pool exhibits an old forest bed with remains of trees 39 feet below a similar tide. The sections were all seen during the construction of the docks. The Cheshire coast at Leasowe presents phenomena of the same kind, but with less apparent subsidence, being 3 feet at Leasowe Castle, and 8 feet at Dove Point. At the latter place there are two higher land surfaces divided by beds of silt.

From these sections the author concluded that a subsidence of the land of nearly 50 feet was indicated, and that it was uniform over its whole extent, a conclusion confirmed by observations in other places on the same coast. The differences in the amount of the depression shown by the several sections merely indicate the varying elevation of the original surface. The subsidence of the lowest submarine forests probably caused a considerable extension of the river Mersey about the time of the occupation of Great Britain by the Romans. The sinking of the old forest beds of Leasowe, Dove Point, and Formby is known to be within the historical period.

Notes on two Ichthyosauri to be exhibited to the Meeting. By C. Moore, *F.G.S.*

The vertebræ, paddles, and other parts of the skeleton,—also the eye, the skin, the contents of the stomach, and even the ink-bag of the undigested cuttle-fish,—having been carefully exposed, by the careful manipulation of one of the nodules, the specimens were exhibited by Mr. Moore in a developed state,—they having been exhibited at a previous Meeting at Cheltenham in an undeveloped state, on which occasion Mr. Moore promised to produce them at a future Meeting properly developed. Another specimen commented upon was a nodule untouched, and represented a stone "mummy" of another Ichthyosaurus, upwards of five feet long, which Mr. Moore expected to find in a most perfect state of preservation when he could work it out. This, he believed he could also show, fed upon the cuttle-fish millions and millions of years ago.

Information from Professor Haidinger *respecting the Present State of the Imperial Geological Institution of Vienna. (Communicated by* Sir R. I. Murchison.)

Sir R. I. Murchison said, that important Institution was one of many which were very likely to have been abolished in the course of the changes which were going on in the empire of Austria. That excellent Institution was founded by his distinguished friend Haidinger, one of the first mineralogists in Europe, who now wrote that the authorities having been changed, and public opinion having been expressed so strongly in favour of his Institution, the Government had conceded all the terms in favour of geological science which had been formerly granted, and the Imperial and Royal Geological Institution of Vienna was reinstated upon its old foundation of 1848.

Maps and Sections recently published by the Geological Survey, exhibited by Sir R. I. Murchison.

On a Dinosaurian Reptile (Scelidosaurus Harrisoni) *from the Lower Lias of Charmouth. By* Professor Owen, *M.D., F.R.S., F.G.S.*

The author said that the reptile of which he was about to speak belonged to the remarkable order exhibiting modifications of the reptilian structure as we now know it in crocodiles and lizards, as adapted for life on land. The evidences as to the order Dinosauria were first made known by the discoveries of Mantell and Buckland, from examples found in this country. The remains had been found in the upper greensand deposits of our cretaceous system, through the Wealden, and (as regarded the Megalosaurus) as far down as the great oolitic system; but until very recently that was the oldest formation from which any evidence of a Dinosaurian reptile had been the property of science. Mr. Harrison, a retired medical gentleman residing at Charmouth on the Dorset coast, near the magnificent liassic cliffs that had afforded such rich evidences of marine reptilia, had devoted his leisure to the collection of fossil remains from those cliffs. About three years ago, Mr. Harrison obtained, from a part of the cliff which was an upper member, if not the uppermost, of the Lower Lias, some fragments of limb-bones of so novel a character that he sent them to him (Professor Owen) for his opinion. He was surprised to receive such specimens from that locality and formation, seeing that the fragments presented unequivocal evidence of the Dinosaurian order, and of a species which, judging from the femur, was closely allied to the Iguanodon. Mr. Harrison was quickened in his researches by receiving a reply to this effect; he offered rewards to the quarrymen, and at length he became possessed of the most complete skeleton of a Dinosaurian reptile ever obtained from any formation or locality. Fortunately it was almost complete as regarded the skull and dentition —a part of the osteology of the order which it was most desirous to know. Preceding inquiries had only made us acquainted with the lower jaw of the Iguanodon, part of the lower jaw of the Megalosaurus and Hylæosaurus, together with some small obscure fragments of the upper jaw of the Iguanodon. As to the cranium, our knowledge was a blank until this happy discovery. The skull was entire, with the exception of the end of the snout; in fact, it was entire for all the purposes of the comparative anatomist. So were the neck and trunk vertebræ, the sacrum, the pelvis, and a great portion of the vertebræ of the tail. The author described in detail the various portions of the skeleton, pointing out where they nearly resemble those of the Iguanodon and the Megalosaurus. These descriptions, with illustrations, would appear in the forthcoming volume of the Palæontographical Society.

On the Remains of a Plesiosaurian Reptile (Plesiosaurus Australis) *from the Oolitic Formation in the Middle Island of New Zealand. By* Professor Owen, *M.D., F.R.S., F.G.S.*

The author, premising a quotation from his 'Palæontology,' that "the further we penetrate into time for the recovery of extinct animals, the further we must go into space to find their existing analogues," and that "in passing from the more recent to the older strata, we soon obtain indications of extensive changes in the relative position of land and sea," cited some striking examples in proof of these propositions from the reptilian class. The Mosasaurus of the cretaceous series occurs in that series in England, Germany, and the United States. The Polyptychodon occurs in the same series at Maidstone and at Moscow. Toothless Lacertian reptiles have left their remains in triassic deposits at Elgin, in Shropshire, and at the Cape of Good Hope. Dicynodont reptiles occur in the same formation at the Cape and in Bengal. The Plesiosaurus, with a more extensive geological range through the Jurassic or oolitic series, has left representatives of its genus in those mesozoic strata in England and at her antipodes. Evidence of this extreme of geographical range had been submitted to Professor Owen by Mr. J. H. Hood, of Sydney, New South Wales, obtained by him from the Middle Island of New Zealand. This evidence consisted of two vertebral bodies or centrums, ribs, and portions of the two coracoids of the same individual, all in the usual petrified condition of oolitic fossils. Their matrix was a bluish-grey clay-stone, effervescing with acid; the largest mass contained impressions of parts of the arch and of the transverse processes of nine dorsal vertebræ, and of ten ribs of the right side. Portions of five of the right diapophyses and of six of the ribs remained in this matrix. The bones had a ferruginous tint, contrasting with the matrix, as is commonly the case with specimens imbedded in the Oxfordian or liassic clays. The impression of the first diapophysis and of its rib show the latter to have been articulated by a simple head to its extremity, as in the Plesiosaurus; but the succeeding rib had been pushed a little behind the end of its diapophysis, and the same kind of dislocation had placed the five following ribs with their articular ends opposite the interspaces of their diapophyses. The ninth rib had nearly resumed its proper position opposite the end of the diapophysis, but at some distance from it; the impression of the tenth rib shows the normal relative position of the pleur- and diapophyses. The ribs are solid, of compact texture, cylindrical, slightly curved, the fragments looking more like coprolites than bone; they are about an inch in diameter, with but small intervals of, say, one-third of an inch, slightly expanding as they recede from the transverse process, and slightly contracting to the lower end. The first, terminating in an obtuse end of ½ an inch diameter, is 7 inches long; the second is 8 inches long; the third is 8½ inches; the fourth rib is 9 inches long. The extremities of the others are broken off with the matrix. The separated fossils sent from New Zealand included the mesial coadjusted ends of a pair of long and broad bones, thickest where they were united, and becoming thinner as they extended outwards, and also towards the fore and hind parts of the bone, both of which ends were broken away. On one side the surface of the bone is convex lengthwise, and slightly concave transversely. On the opposite side the contour undulates lengthwise, the surface being concave, then rising to a convexity, where a protuberance has been formed by part of the coadjusted mesial margins of the bone; transversely this surface is slightly concave. A similar but less developed median prominence is seen at the middle of the medially united margins of the coracoids in the *Plesiosaurus Hawkinsii*, and the author regards the above-described parts of the New Zealand fossils as being homologous bones. But a more decided evidence of the Plesiosaurian nature of this antipodeal fossil is afforded by the vertebral centrums. They have flat articular ends, with two large and two small venous foramina beneath. The neurapophysial surfaces, showing the persistent independence of the neural arch, are separated from the costal surfaces by about half the diameter of the latter. These are of a full oval figure, 1 inch 3 lines in vertical, and 1 inch in fore-and-aft diameter. On one side of one of the centrums the rib has coalesced with the costal surface. The following are the dimensions of this centrum:—Length 1 inch 9 lines, depth 2 inches 2 lines, breadth of articular end 3 inches 6 lines. The non-articular part of the centrum offers a fine silky character. The shape and mode of articulation of the cervical and dorsal ribs, the shape and proportions of the coracoids concur with the more decisive evidence of the vertebræ in attesting the Plesiosauroid character of these New Zealand fossils, and, pending the discovery of the teeth, the author provisionally referred them to a species for which he proposed the name of *Plesiosaurus Australis*. The specimens had been presented by Mr. Hood to the British Museum.

On certain Markings in Sandstones. By W. PATTERSON.

On a new Bone-cave at Brixham. By W. PENGELLY, *F.G.S.*

This cavern (a second new one) was discovered in March last; it is rich in fossil bones; and the district in which it exists has become famous in connexion with these caverns. The town of Brixham occupies a valley running nearly east and west, which is separated from Torbay on the north by a limestone hill, known as Furzeham Common, 150 feet above the sea, while the southern boundary consists of four hills forming a chain parallel to that on the north, but extending a mile further eastward, where it terminates in Berry Head, the southern horn of Torbay. In Windmill Hill, the second (from the west) of the four, the celebrated cavern was discovered in 1858; and in the third is the well-known Ash Hole. After a cessation of upwards of twenty years, quarrying operations had been partially resumed at Bench, on the Torbay slope of Furzeham Hill; and these led to the discovery of the new cave. The quarry is being worked at right angles to the coast-line. Near the top of the west or back wall, and near the angle formed by the junction with the south wall, there is a dyke of breccia, made up of bones, reddish clayey earth, and angular pieces of limestone, evidently from the adjoining rock. The earth is precisely similar to that in which the bones are found imbedded in the other Torbay caverns. The base of the breccia is on the same level as the bone-bed in the Windmill Hill Cavern; and there can be no doubt it filled, either wholly or partly, a north and south fissure. Nearly the whole of the dyke was revealed during the old quarrying operations. In the exposed face there were visible several fine bones; but even a remarkably fine left ramus of a lower jaw bristling with teeth, of the Cave Hyæna, not only did not attract the attention of the workmen at the time, but it remained unobserved for twenty-two years. Soon after quarrying was resumed, in March last, the removal of the remnant of the outer wall caused a portion of the dyke to fall. Numerous bones were now so conspicuous amongst the earth and stones, that the principal workmen soon collected several hundreds, consisting of teeth, jaws, skulls, vertebræ, and portions of horns, with a large quantity of unidentifiable bone-débris. There is no probability that the so-called dyke formed originally portion of a mass filling a cavern, great part of which was destroyed by the workmen twenty years ago, for in the neighbourhood it was known that cave bones would fetch good prices. In fact, the handwriting of the departed limestone was visible on the breccia sheet that had been so long exposed. Near the southern foot of the dyke is the mouth of a small tunnel, with a stalagmitic floor; its extent is not known. In the southern wall of the quarry are two large chambers, filled with the reddish earth and limestone débris; they are known to be connected, but it is not known whether they communicate with the tunnel; it is exceedingly probable, however, that they are all parts of one considerable cavern. All the materials of the dyke undoubtedly fell, or were washed in from above; giving a good example of what probably occurred at Orestone, near Plymouth, where observed phenomena compel the belief that the fossil bones must in this way have found ingress to the cavern, though lines of fissure are not always very distinct there. The owner had now decided to explore the chambers and tunnel himself; but although he had declined to sell the right so to do, he had always given the author access, had promised to enable him to note every fact discovered, and he had also lent the exhibited specimens. There is a great field for exploration at Brixham. It is to be hoped that quarrymen may not in future be so blind to their own interests as to lay open a dyke of osseous breccia without discovering that they have done so; and that a proprietor will not, as in a case within the author's knowledge, admit that he had filled up a cavern, which he called "a large hole in the rock," by "throwing twenty cartloads of rubbish into it."

On the Recent Encroachments of the Sea on the Shores of Torbay. *By* W. PENGELLY, *F.G.S.*

Hard Devonian limestones, fissile and jointed, formed, the author said, the two projecting horns of Torbay. Sandstones and conglomerates form the hollow of the bay, and have been much worn away within the memory of man, especially at Livermead, which is only preserved by continual engineering labour. The process of erosion by the sea was explained by the author as something like a succession of honeycombing, sometimes by insulation of portions of the cliffs. On the slates and limestones the sea more slowly produced excavations, which storms enlarge. The effects of the severe storm of October 1859 on the cliffs, beach, roads, &c. of Torbay were described in detail, and the importance of such storms as modern agents of change was dwelt upon.

On the Relative Age of the Petherwin and Barnstaple Beds. *By* W. PENGELLY, *F.G.S.*

In a paper on the Chronological and Geographical Distribution of the Devonian Fossils of Devon and Cornwall*, read before this Section last year at Oxford, I expressed the provisional opinion that there was not sufficient evidence to warrant the chronological separation of the Petherwin and Barnstaple beds. More recently I have reconsidered the question, and have found reasons for changing my opinion.

* See 'Report' for 1860, p. 91.

The fossils recorded as occurring in the two areas are as shown in the following Table.

TABLE I.

	Petherwin.		Barnstaple.	
	Genera.	Species.	Genera.	Species.
Zoophyta	3	3	1	1
Echinodermata	1	1	4	6
Crustacea	2	2	1	1
Bryozoa	2	2	3	3
Brachiopoda	7	20	8	26
Lamellibranchiata	7	14	8	21
Gasteropoda	6	9	7	10
Cephalopoda	5	21	2	8
Totals	33	72	34	76

Assuming the higher antiquity of the South Devon and contemporary beds, it follows that the fossils common to it and Petherwin, or Barnstaple, or both, were contributions from it to them. Regarded thus, the populations of the two areas were made up as below.

TABLE II.

	Petherwin.	Barnstaple.
	Species.	Species.
Silurian	1	1
Lower Devonian	15	13
New (peculiar)	44	50
New (common)	12	12
Carboniferous	13	16

By "peculiar" is meant such species as, in England, are found in Petherwin or Barnstaple only; "Common" marks those found in both, but not elsewhere in British *Devonian* rocks; and "Carboniferous" is used to designate the species common to deposits of that age and Petherwin, or Barnstaple, or both, exclusive of six found also in Lower Devonian deposits. The "Carboniferous" figures in Table II. are not in addition to the previous numbers; the totals (72 and 76) are, of course, complete without them.

In order to show the *relative* value of the figures just given, the following Table has been calculated on the method of putting each total (72 and 76) equal to 1000, and equating the figures in Table II. to it.

TABLE III.

	Petherwin.	Barnstaple.
	Species.	Species.
Silurian	14	13
Lower Devonian	208	171
New (peculiar)	611	658
New (common)	167	158
Carboniferous	181	211

A glance at the Table shows that, of the two, Petherwin is the nearest to the Lower Devonian horizon, and the most remote from the Carboniferous.

The fossils of the two areas belong to forty-six genera, of which thirty-three are represented by the Petherwin, and thirty-four by the Barnstaple series; twenty-one are common to both: hence twelve are peculiar to the first, and thirteen to the last area.

The forty-six genera may be divided into two groups: namely, 1st, those characterized by a considerable maximum specific variety or development before or after Petherwin and Barnstaple times; and 2nd, those that are not thus distinguished.

The first of these groups (which alone we have to consider here) contains thirty-one genera, of which six may be said to belong to the *past*, and twenty-five to the *future*; the age of Petherwin and Barnstaple being the chronological stand-point.

The "future" division (the only one sufficiently numerous to be of service in this inquiry) consists of two series: namely, 1st, those genera which are equally represented in the two sets of beds; and 2nd, those that are not. Evidently the latter series alone can supply information on the present question. It is made up of the fifteen genera named in the following Table, in which the columns headed P. B. C. exhibit the number of species belonging to each genus which occur in the Petherwin, Barnstaple, and British Carboniferous beds respectively.

TABLE IV.

Genera.	P.	B.	C.
Amplexus	1	..	5
Cyathocrinus	1	3	10
Pentremites	..	1	11
Glauconome	..	1	5
Fenestella	1	..	19
Chonetes	..	2	16
Productus	1	3	48
Modiola	1	..	16
Axinus	1	..	9
Cypricardia	..	1	9
Nucula	..	4	14
Sanguinolites	..	2	15
Loxonema	3	1	14
Macrocheilus	..	1	16
Nautilus	1	..	40
Totals	10	19	247

From the Table we learn that nine of these genera are found in Barnstaple and not in Petherwin, or are more largely represented in the former than in the latter; and that nineteen species represent the ten genera found in the former area, whilst no more than ten the eight genera of the latter. Hence the genera, like the species, suggest that the Barnstaple beds are somewhat more modern than those of Petherwin.

We are prepared, by even a slight acquaintance with the geographical distribution of existing organisms, to find that deposits strictly contemporary, lithologically similar, and closely connected geographically, have certain fossils peculiar to each. But unless we recognize time as a factor, it will be difficult to explain the facts that Petherwin and Barnstaple have together yielded as many as 131 species of fossils, yet have no more than seventeen in common; that the fossils belong to forty-six genera, of which twenty-five are restricted to one or other of the two areas, having amongst them the rich genus *Clymenia* with its eleven species, all closely confined, in Britain, to Petherwin, yet occurring in Continental Europe; that the remaining twenty-one genera are represented, in the two areas, by eighty-six species; but the representatives are rarely identical in the two sets of beds, the *peculiar* being to the *common* as 69 to 17, that is about 4 to 1. Contend that these beds are strictly contemporary, and the facts remain to puzzle; grant but the lapse of time, and, at least, part of the difficulty disappears, and thereby furnishes an argument in favour of the opinion now advocated.

Returning for a moment to Tables II. and III., it will be seen that the Barnstaple beds have a smaller number of species in common with the Lower Devonian and even the Petherwin beds, than with the Carboniferous; hence they may be considered as belonging rather to the last than to the Devonian series, or possibly they may have to be regarded as "Passage beds" between them.

On the Age of the Granites of Dartmoor. By W. Pengelly, *F.G.S.*

It has long been well known that the Dartmoor granites have sent veins into the culmiferous rocks of North and Central Devon, and that the latter are much bent and contorted, probably by the intrusion of the former*; consequently the granites are more modern than the rocks they have thus invaded and disturbed.

Geologists, however, are by no means agreed respecting the age of the granites relatively to that of the deposits of the county more modern than the culmiferous beds. Sir H. De la Beche regards them as more ancient than the red conglomerates and sandstones of South Devon, but says, "The evidence is not always so clear as could be desired; for among all the pebbles of the red conglomerate extending from Torbay to Exeter, we have not been able to detect any portion of it, though the granite ranges so near that part of the red conglomerate. In the tongue of red sandstone and conglomerate which runs from Crediton by North Tawton and Sampford Courtney to Jacobstow, we have, however, detected pebbles like some varieties of Dartmoor granite†." This is certainly not a very pronounced opinion in favour of this evidence; in another place, however, he speaks somewhat more decidedly in favour of the pebbles‡; but he appears to base his chronological opinion mainly on the fact that the red sandstone series are found resting quietly on the basset edges of the upturned culmiferous beds§.

Mr. Godwin-Austen, however, is of a different opinion. "As no granite pebbles," he says, "have been found among the various materials of which the new red conglomerate is composed, we may conclude that at the period of its accumulation the granite of Dartmoor could not have been exposed, particularly when we bear in mind that the two formations are at present separated only by the valley of the Teign.

"The beds of the Greensand of the Haldons and the Bovey Valley, in the thin mica, sharp quartzose crystals and seams of felspar, suggest that they may have resulted from a decomposed granite district; but here, again, although fragments of all the older rocks occur in the conglomerate beds at the base of the Greensand, granitic pebbles are altogether wanting; nor do we meet with them until we arrive, in ascending order, at those superficial accumulations which cap the Haldons. Possibly, then, the rise of the granite of Dartmoor in its present form may belong to a period comparatively modern‖".

Happening a few years ago to be at North Tawton, I mentioned the subject to Mr. Wm. Vicary, then resident there, who at once took me to the conglomerate, and in a very few minutes extracted two or three pebbles, which we both regarded as of Dartmoor derivation. Whether they were strictly *granite* in the technical sense of the word may possibly be questioned; and it is certain that much of the granitic mass of Dartmoor will not pass muster as *true granite*¶; but that the pebbles found at North Tawton were of Dartmoor extraction, and can be matched by thousands in the rivulets and torrent-courses of the Moor, I have no manner of doubt.

In August 1861 I met Mr. Vicary at Exeter, where he now resides, and again spoke of the Tawton pebbles. He informed me that he had found unmistakeable granite pebbles in the red conglomerate at the base of Haldon, a well-known hill about five miles south of Exeter. He also informed me that since his discovery his attention had been called to the fact that Mr. Brice, in his 'History of Exeter,' mentions the occurrence of pebbles of granite in the red conglomerate at Haldon**.

We at once started for the spot, and passing through Alphington and Kennford,

* Sir H. De la Beche's "Report," p. 165; Professor Sedgwick and Sir R. I. Murchison in Geol. Trans. vol. v. pt. 3. p. 686–7; Mr. Godwin-Austen, Geol. Trans. vol. vi. pt. 2. p. 477; and Mr. Ormerod in Quart. Journ. Geol. Soc. vol. xv. p. 492.

† Report, p. 166.

‡ Mem. Geol. Survey, vol. i. p. 228.

§ Report, p. 166; see also 'Geol. Observer,' p. 648.

‖ Geol. Trans. vol. vi. pt. 2. p. 478.

¶ See Sir H. De la Beche's "Report," p. 158.

** History of Exeter, by Thomas Brice, 1802, p. 114.

and leaving the great road from Exeter to Plymouth, on the right, for that which passes over Haldon, in a more easterly direction, to Newton Bushel, reached our ground about five miles and a half from Exeter. Mr. Vicary at once pointed out in the red conglomerate one or two well-marked fragments of the true Dartmoor series of rocks, but so far disintegrated that it was impossible to extract them in their integrity; a further search was soon rewarded with several less perishable specimens, and amongst them representatives of each of the three kinds of granite described by Mr. Godwin-Austen as occurring on Dartmoor: there were samples of schorlaceous granite, porphyritic granite, and elvan*. On our way back to Exeter we detected several well-marked specimens near Peamore, about two miles and a half from the city.

Though granite pebbles may not have been met with in the conglomerates and sandstones of Torbay, it by no means follows that these rocks are destitute of Dartmoor detritus. Every one who has paid attention to these sandstones must be well aware that in many cases they are eminently micaceous—doubtless a result of the destruction of a large amount of pre-existing rock, such as granite, of which mica was a constituent. Nor is it difficult to understand that whilst boulders and pebbles might be unable to force a passage to what is now the South Devon seaboard, comparatively small thin flakes of mica might succeed in accomplishing the journey. We may have here an indication that the direction of the *prevailing* and powerful currents was not eastward, but north-east and northerly—not from Dartmoor to the coast of South Devon, but towards Haldon and North Tawton.

The granites of Dartmoor, then, are limited in age, on the side of antiquity by the culmiferous beds of Devon, and on the modern side by the red conglomerates: what is the place of these in the chronological scheme of the geologist? The answer has long been given respecting the first: "The upper division of the culmiferous beds contains fossils identical with those in the upper division of the coal-measures†." But the age of the conglomerates is less easily determined. That they belong to the New Red Sandstone there can be no doubt, since they are above the Upper Coal-measures and underlie the Lias; but whether Upper or Lower New Red, that is, Triassic or Permian, is not so certain as could be wished. They are entirely destitute of fossils, excepting such only as occur *in* the pebbles. The sandstones are evidently of littoral origin; their surfaces frequently display fossil sea-ripples, sun-cracks, and impressions of rain-drops; but no footprints or organic traces have ever been detected on them; there are no palæontological indications of their age.

More than one eminent geologist has been struck by the angular character of the fragments composing the conglomerates (more correctly breccias), and has remarked that, in its physical character and general appearance, the formation is rather Permian than Triassic. It is, as is well known, coloured in our geological maps as on the horizon of the Lower Trias. The granite pebbles of Haldon may perhaps go far to confirm this decision.

Whatever may be our opinions respecting the origin of granite, whether we hold it to be a strictly igneous or a thermo-aqueous product, an original or a superimposed phase of rock existence, there is probably no doubt that it was formed in Plutonic depths, a hypogene formation requiring enormous pressure for its elaboration.

Mr. Sorby estimates the pressure under which the St. Austel granite was formed as equivalent to that of 32,400 feet of rock‡. He gives no estimate for Dartmoor, but we shall probably not *exceed* the truth in taking this, his lowest Cornish estimate, which gives us a pressure equivalent to that of a pile of rock six miles in thickness; but as the pressure was probably due to the expanding power of some agency acting beneath or within the granitized mass, requiring resistance and not pressure, strength and not weight in the overlying crust, we may content ourselves with a small fraction of this. Still there must have been a crust of very great thickness at and after the close of the Carboniferous period, or the granitic form could not have been assumed by the mass beneath; and this crust must have been stripped off and the granite laid bare before the era of the accumulation of the red conglomerates, or

* Geol. Trans. vol. vi. pt. 2. p. 477.

† Prof. Sedgwick and Sir R. I. Murchison in Geol. Trans. vol. v. pt. 3. p. 687.

‡ Quart. Journ. Geol. Soc. vol. xiv. p. 494.

no pebble could have found its way to Haldon. Even if some paroxysm be supposed to have uplifted the granite in a solid state, so as to shiver the overlying crust and thereby to facilitate the work of denudation, still the time required, even thus, appears to be so very great, so completely overwhelming, so entirely incapable of compression, that it is impossible to regard the red conglomerate as belonging to the Permian formation, the representative of the period next succeeding the Carboniferous. Indeed if we conceive of the Dartmoor granite being called into existence, as such, at or subsequent to the close of the Carboniferous period, and laid bare prior to the era of the Lower Trias, and that, during the interim, a pile of rocks of considerable thickness, covering an area of 200 square miles, had been stripped off, we get a rough yet overwhelming measure of the chronological interval, the Permian period.

The facts of the case appear to require the belief—

1st. That the Dartmoor granite is not older, at most, than the close of the Carboniferous period.

2nd. That it was exposed at the earth's surface when the materials of the red conglomerate were being accumulated.

3rd. That the conglomerates are not of higher antiquity than the Lower Trias.

4th. That the Permian period was one of great duration.

Notice of the Post-glacial Gravels of the Valley of the Thames. By Professor Phillips.

On the Gold of North Wales. By T. A. Readwin, *F.G.S.*

The author confined his observations in this paper to an area of about twenty square miles, situated north of the turnpike road leading from Dolgelly to Barmouth. Professor Ramsay has ably described the geology of this district in a communication to the Geological Society of London in 1854, entitled "The Geology of the Gold-bearing Districts of Merionethshire." The Dolgelly district is bounded by the river Mawddach, the great Merioneth anticlinal range, and the little river Camlan. In this district are found the Cambrians, overlaid by the Lower Silurian Lingulas. The Cambrian rocks are coarse greenish-grey grits, and the Lingula-flags are arenaceous slaty beds, interstratified with courses of sandstone. Calcareous and greenstone dykes frequently penetrate both the Cambrian and the Silurian rocks. The metalliferous products are chiefly argentiferous galena, copper pyrites, blende, manganese, and mundic, associated frequently with gold. According to Sir R. Murchison, "the most usual position of gold is in quartzose veinstones that traverse altered palæozoic slates, frequently near their junction with eruptive rocks, whether of igneous or of aqueous origin. The stratified rocks of the highest antiquity, such as the oldest gneiss or quartz rocks, have seldom borne gold; but the sedimentary accumulations which followed, or the Silurian, Devonian, and Carboniferous (particularly the first of these three), have been the deposits which, in the tracts where they have undergone a metamorphosis or change of structure, by the influence of igneous agency or other causes, have been the chief sources whence gold has been derived." After referring to the opinion of Professor Ramsay that gold in the Ural Mountains, Australia, &c. occurred in rocks of a similar age and character, the author stated that Sir R. Murchison's statement is singularly corroborated by the position of the quartzose vein in the Clogau Mine, distinguished as the "Gold Lode," which traverses altered palæozoic slates near the junction of an eruptive bar of porphyritic greenstone; and the same law appears to obtain also with respect to all gold-bearing quartzose veins of the Dolgelly district, upon the ores of which he had made a very large number of experiments during the past eight years. There are in this district about twenty localities in which gold has been discovered visible in quartz, or associated more or less with galena, blende, copper-pyrites, telluric bismuth, carbonate of lime, schist, baryta, iron-pyrites, &c. By far the richest discoveries of gold have been made at the Dol-y-frwynog, Prince of Wales, Cambrian, and the Clogau mines. Gold has also been found in the "Marine drift" by the Hon. F. Walpole, Sir Augustus Webster, the author, and others, a piece of which was exhibited. Mr. Arthur Dean, in a paper read before the British Association in 1844, stated that a complete system of auriferous veins exists throughout the whole of the Snowdonian or Lower Silurian formations of North Wales. Upon the faith of this, much money was spent at the Cwmheisian mines, and very little gold obtained by smelting operations, for reasons which are now not very difficult to understand. Much money was also spent about ten years afterwards at the same place, after setting the most eminent assayers to work, to prove the truth of Mr. Dean's statement, in erecting machinery, which produced even less gold by amalgamation than the former method. Although it was then held as an axiom that gold always exists in a metallic state, that mercury has always an affinity for gold, and therefore, wherever gold is present in minerals, mercury will necessarily dissolve it, in this instance, however, it did not prove the case, and the result of operations upon 150 tons came at length to be considered as an enigmatical failure, as the following extracts from the experiments made at the time will show. Here followed a detailed account of experiment No. 7, made on 4½ tons of metalliferous minerals which were triturated in 42 lbs. of mercury. Ten pounds of this on distillation gave 70 grains residual metal, containing 18·4 grains of gold. A qualitative analysis of this residual metal gave gold, silver, lead, bismuth, zinc, arsenic, and also traces of copper and iron. The distilled mercury contained traces only of zinc and arsenic. It had been proved before the experiment, and also since, that the 4½ tons of mineral contained several ounces of the "Royal metal," but the quicksilver neglected it for associates of less dignity, though intrinsically of more real utility. This, however, was not the result expected. At the Dol-y-frwynog mine, about two years afterwards, Sir Charles Price operated similarly upon several tons of material, but with the same provoking failure as before. At present the Clogau mine is the most interesting and profitable. It stands at an elevation of 1000 feet above the level of the sea. The "Saint David's" or "Gold Lode" is the most remarkable feature. After giving some descriptions of this mine, he desired to notice especially that this lode is at the junction of the Cambrian sandstones and the Lingula flags of the Lower Silurian rocks. A quantity of what was called "poor copper ore" was raised from this lode and sold many years since; but in 1854 the refuse of this "poor copper ore" was examined, and indications of native gold in considerable quantities were found. Some of this refuse ore was put to the test, and in one instance, to his knowledge, 100 lbs. weight yielded 14½ ounces of gold. Many other experiments have been made by various persons with equal success; but owing to the uncertainty of the operation of amalgamation on the one hand, and the mines themselves being subject to two Chancery suits on the other, the general value of the lode, in bulk, has not until recently been determined. After some observations on the processes of assay—which he did not think would give the approximate value of auriferous minerals, notwithstanding that the contrary had been asserted by many eminent men—he referred to a series of thirteen experiments made by himself last autumn upon 112 pounds of auriferous quartz from the Clogau mine, duly prepared and sampled by Johnson and Son, of London. The whole quantity gave 25 oz. 16 dwts. 7 grains of amalgam, and of fine gold, 8 oz. 5 dwts. 19 grains. An authority in such matters had declared the value of the gold by assay to be £9 per cwt., while he declared it to be £30; in the latter case samples of 7 lbs. each, instead of the usual 400 grains, had been operated on. He would now state the result of actual working operations for gold at the Clogau mine since the beginning of the year. This statement showed that 207 tons 8 cwt. of quartz gave 1314 oz. of fine gold; 3 tons of the best of this quartz gave no less than 976·6 oz. of gold. If they added 56 ounces obtained from 5 tons in 1860, it showed a total quantity of 1370 ounces of gold from 212 tons of auriferous mineral, being at the rate of 6½ ounces per ton. This, he believed, was the first instance of a hundredweight of gold having been obtained from the crown lands of this country, the value of which was £5300. This "Royal Mine" paid a royalty of $\frac{1}{12}$ to the crown. The cost of extraction had been very inconsiderable, and there was a probability of an equal yield of gold for some time to come.

P.S. The total amount raised from this lode to 19th May, 1862, is three hundredweight.

On the Details of the Carboniferous Limestone, as laid open by the Railway Cutting and Tunnel near Almondsbury, north of Bristol. By — RICHARDSON, *C.E.* (*Communicated by* Sir R. MURCHISON.)

Geologists obtained a great deal of very available and useful knowledge from the examination of the cuttings and tunnels in railroads; and they had not of late years derived more information from a single cutting than that to which he would point their attention. There was a branch railway making from Bristol, from the Great Western line, and which was to traverse the Severn. In making this traverse, it was necessary to cross a ridge of limestone near Almondsbury, the railroad cutting through the carboniferous limestone. In one part strata were subject to very great contortions. In some parts there were broken bands of coal, thrown about in an extraordinary way. The whole of the highly inclined strata were surmounted by new red sandstone. It was remarkable that there was in this cutting an enormous amount of calcareous and other grits which seemed to form a regular part of the mountain limestone. There were also large red masses, evidently formed by concretion.

Sir R. Murchison exhibited a detailed diagram prepared by Mr. Richardson, and, having visited the locality, explained the chief phenomena to the Section, promising that the tract should be examined carefully by one of the Geological Surveyors.

On the Nature of Sigillariæ, *and on the Bivalve Shells of the Coal. By* J. W. Salter, *A.L.S., F.G.S.*

The object of the communication was to describe some specimens of *Sigillaria* which have the appearance of having grown in water, inasmuch as they have the stem swelled at short intervals, and show scars like those of the rootlets of *Stigmaria* at these swollen varices. The scars in question appear *between* the ridges on which the rows of leaf-scars are arranged, and terminate where the swelling ceases. Such swellings are seen in several fine specimens, in the Manchester Museum, of *Sig. (Favularia) tessellata, S. nodosa,* and *S. hexagona.*

That the *Sigillariæ* grew in water has long been the opinion of Mr. Binney (1840), and (independently) also of Professor H. Rogers (1842). The tracks of large worms in the sediment, the spiral annelides (*Spirorbis*), and the *very frequent* intermixture of undoubted sea-shells, have led the former author to speculate freely on their growth in sea-water. And the presence of very salt water in coal-mines, and of soda in all coal, as Dr. Percy affirms, is a confirmation of this belief.

The freshwater character of the coal-growths has been assumed chiefly from the occurrence of shells like *Unio* in it (*Anthracosia* of King). These, however, differ in some important particulars from true *Unio,* and they are found associated with shells (*Anthracomya*) which appear, from their wrinkled epidermis, to be related to the *Myadæ.* They occur, too, though much less frequently, with true *marine* forms, *Productus, Spirifer,* &c., in the ironstones; and one, the common *Anthracosia acuta,* is even found in the mountain limestone shale, where the fossils are all marine.

On the Granitic Rocks of Donegal, and the Minerals associated therewith. By R. H. Scott, *M.A.*

The author gave a short account of a mineralogical tour made by him, in company with Professor Haughton, in the course of the summer, the results of which seemed to throw some light on the possible origin of granite. The district visited was Donegal, which county consists mainly of gneiss and mica-slate, and is traversed in a N.E. direction by an axis of granite. This granite is of a peculiar composition, containing two felspars, one orthose, and the other, not albite, as in the granite of the Mourne mountains, but oligoclase—a mineral whose occurrence in the British Islands had only been noticed within the last twelve months. Professor Haughton, to whom this discovery is due, was unfortunately unable to attend the Meeting. The facts were briefly these:—The granite contains oligoclase and quartz, which combination appears to be a proof that the rock never was in a melted condition, as in that case these two minerals would have acted on each other and formed common felspar. It lies in beds corresponding to the general lie of the strata of the country, and in its character is essentially gneissose; and, lastly, at points inside the area of the granite, metamorphic rocks (limestones and slates) are found with their bedding, which is nearly vertical, unchanged. The condition of these rocks is very similar to that of the same rocks outside the granite area; and it is a point of great interest to determine how they got there. The solution of this offered by the author of the paper was that the whole of the rocks had been originally stratified, and had been subjected to some actions which are termed metamorphic. The result of such action was to convert some into granite, some into gneiss, and some into crystalline limestone and mica-schist, without very much altering their relative positions. The possibility of granite being produced by other means than simple heat seemed to them to be proved by the occurrence of felspar in quartz veins, which are usually admitted to have been filled by means of infiltration. The author stated that there were several points in connexion with these granites which showed a close relation between them and the granites of Norway. The whole question required a careful chemical and mineralogical examination, which could not be concluded for some time. Among the types of rock found in Donegal is a syenite, the felspar of which is oligoclase. The origin of this rock the authors are disposed to attribute to the addition of limestone to the granite. A similar syenite occurs at Carlingford, but contains anorthite, a felspar which would result from the admixture of a larger quantity of limestone than is necessary to produce oligoclase, and has been proved by Professor Haughton to have such an origin. The anorthite syenite never occurs unless limestone is present in large excess, which is not the case in Donegal. In conclusion, Mr. Scott mentioned that the district described by him was very rich in minerals, some of which were extremely rare, and that he entertained no doubt that a more careful examination would largely increase their number.

On the Elsworth Rock, and the Clay above it. By HARRY SEELEY.

The Elsworth rock is a limestone somewhat oolitic and pyritous, divided by a dark clay into upper and lower beds characterized by different fossils. At the village of Elsworth the entire thickness is not more than 14 feet, a thickness which a well-sinking three miles S.S.W. showed it still to retain. The dip being in this direction, and of about 1 foot in 200, it followed that another stone band found at St. Ives, $4\frac{1}{2}$ miles north, would be 130 feet lower down. This rock, at a point midway between St. Ives and Elsworth, was found in a well to be some 5 feet thick; at St. Ives what remains of it is rather thicker. It is more earthy than the Elsworth beds, has similar fossils, and is often divided by a thin parting of clay. At Bluntisham, two miles N.N.E. of St. Ives, the Elsworth rock is again met with, the St. Ives rock therefore coming up in a saddle. Another rock is found at St. Neots. As the St. Ives rock occurs at Papworth, little more than two miles west of Elsworth, and St. Neots is six miles west of Papworth, this stone band is regarded as greatly below the other beds. A similar conclusion would be drawn from the fossils of the adjacent clay. At Tetworth, seven miles S.W. of Elsworth, and therefore above the Elsworth rock, a thin limestone of a foot and a half was found.

These rocks mark zones in the clay all distinguished by differing groups of fossils: the St. Neots zone has *Ammonites Duncani*, *A. spinosus*, *A. athletus*, *A. coronatus*, &c.; the St. Ives zone *A. Eugenii*, *A. Mariæ*, *A. cordatus*, *A. Goliathus*, &c.; in the next zone are *A. Babeanus* and *A. alternans*; and in the Tetworth zone *A. Achilles*, *Belemnites excentricus*, *Lima pectiniformis*, *Gryphæa dilatata*, *Ostrea deltoidea*, &c. Above this latter zone no stone bands are known, there being a great thickness of clay which appears to pass gradually into the Kimmeridge clay, the coral rag being wanting. But as there is not the usual break in life, but a blending of the fossils of two clays hitherto distinct, and with them some forms of the coral rag, the coral rag was still present as a *period*, though under a new form. Provisionally this stratum is called the Tetworth clay*. The Elsworth rock is at its base; its upper limit is unknown; in it are very few new and peculiar forms.

The Elsworth rock abounds in fossils, a careful examination of which showed it to be rather the uppermost part of the Oxford clay than a representative of the calcareous grit at the base of the Tetworth clay. A few of the species are—*Am-*

* At the Meeting it was called Bluntisham clay.

monites vertebralis, A. biplex, A. perarmatus, A. Henrici, A. canaliculatus, A. Goliathus, Belemnites tornatilis, B. hastatus; the only described gasteropod, *Pleurotomaria reticulata.* Bivalves: *Pecten fibrosus, P. lens, P. vimineus, Gryphæa dilatata, Lima pectiniformis, Avicula expansa, A. ovalis, A. elliptica, Trigonia costata, T. clavellata, Astarte ovata, A. lurida*, &c. Many new species were noticed; among others, *Gryphæa elongata, Avicula pterosphena, Pleurotomaria amphicelia, Littorina perornata*, &c.

On some Phenomena connected with the Drifts of the Severn, Avon, Wye, and Usk. By the Rev. W. S. Symonds, *F.G.S.*

Alluvial Deposits.—The first point we remark is the great difference which at present occurs in the deposition of silt and alluvium by such rivers as the Severn and Avon, compared with swift-flowing streams like the Wye and Usk, which have a fall of as much as 2½ feet in a mile along their general course. In some localities the Wye has shifted its course, filled up its former channel, and cut out a new bed, within the memory of man, as proved by an old map, which gives the position of the celebrated Ross Oak, now known as the "Burnt Oak," and the river as it flowed a century and a half ago. A broad surface of meadow-land now sweeps where the Wye then flowed, and the river now runs some 70 or 80 yards from the former bank on which that old oak stood. This is not the case with respect to the smoothly flowing Severn and sluggish Avon to anything like the same extent.

The point, however, to which the author would direct attention is, that all these rivers may and do alter their courses, and destroy and re-form their alluvia over and over again, for age after age, without in the slightest degree changing their courses, save as regards the *level alluvial land.*

The Lake Period.—It is well known that there was a time, antecedent to the present configuration of land and river surface, when the Severn, Avon, and Wye flowed, as the river Shannon does now, through a chain of lakes of various sizes, and which lakes are now silted up and form the celebrated "holmes" or river-meadows. The author formerly inferred that the relics of the great quadrupeds found so abundantly on the banks of the Avon, at Bricklehampton and Cropthorne, at Kempsey and other localities on the Severn, were disinterred from banks of mud, silt, and gravel, which were formed on the *shores* of the ancient lakes. It is here that he would correct the inferences that might be drawn from any correlation of these drifts, which contain the remains of the hippopotamus, rhinoceros, elephant, cave-hyæna, and extinct oxen and deer, with the deposits of the *Lake-epoch.* They belong to a *distinct epoch*, and offer a *distinct history.*

Low-level Drift.—Mr. Prestwich has shown that certain drifts and gravel beds above the Avon, Severn, and other rivers, which he designates as "low-level drifts," are altogether antecedent to, and independent of, the detritus which fills up the beds of the former lakes. They belong to a distinct epoch, and represent an entirely different water surface. Instead of dipping under or into the lacustrine deposits, in many localities they dip away from the old lake silts, and are slightly upheaved. They are, in fact, the relics of broad and, probably, rapid rivers, of which the former channel must have been 30 or 40 feet above the level of the silted-up lakes.

The period of the "low-level drift" was, then, anterior to that of the Lake epoch in this part of England; and it is in these beds, and not in the lacustrine drifts of Worcestershire, that the explorer finds such numerous relics of the extinct mammalia.

These beds are well developed near the Avon at Bricklehampton and Cropthorne, and near the Severn at Upton-on-Severn, and near the Ox-eye Gate, about a mile from Tewkesbury, on the Ledbury high road. Near Worcester they may be seen in various localities ranging above the margins of the former lakes. These drifts are also well developed on the banks of the Wye, near Hereford, as at Broomy Hill and the Infirmary. At Brecon, Mr. Symonds found a most interesting old river-margin of well-stratified sand with rolled pebbles, on the slope of a hill, and at a height of 50 or 60 feet above the river Usk.

High-level Drift.—Certain gravels and drifts are found at a *much higher* level above the river-courses than the drifts just alluded to. These gravel-beds cap the summits of very considerable hills in the vale of Worcester. They occur on Tunnel Hill at Upton-on-Severn, on the summit of Corsewood Hill, on Ryal Hill, Twining near Tewkesbury, and at Elmore near Gloucester. They are found along the flanks of the Malverns, where they have yielded the remains of *Elephas antiquus* and *Rhinoceros tichorhinus*, animals that lived during the glacial period, and are therefore properly associated with the northern drift. A fine molar tooth of *Elephas antiquus* has lately been found by Henry Brooks among the gravel which overlies the great masses of angular blocks heaped against the side of a hill, known as Clincher's Mill Wood, near Ledbury.

The author also observed the *high-level* drift at several points in Herefordshire, the principal of which is an excellent section, near the Kite's Nest, on the Hay road, about four miles west of Hereford, and a still better one at Wilcroft near Lugwardine. Another fine molar of *E. primigenius* has been brought to the author of the paper since it was read at Manchester. This fossil is from the high-level drift, 75 feet above the Severn, and is from Twining gravel-pits between Tewkesbury and Brockeridge Common on the Worcester road.

On Subterranean Movements. By Professor VAUGHAN, *of Cincinnati.*

The author stated that the definite relations recently discovered between calorific and mechanical action seemed to have an important bearing on questions relating to the secular refrigeration of the earth and the high temperature of its internal regions, even at the present time. The vast amount of heat supposed to have escaped from our planet during past ages might be reasonably expected to call into existence forces of much greater efficiency than those indicated by the upheaval of lands, or by the violence of earthquakes and mechanical eruptions. Our terrestrial fabric had a strength too limited for the full development of such great calorific powers by the unequal contractions of its different parts; and in a cooling globe compound gases could not be expected to produce any decided mechanical effect, at least without materially altering the composition of the atmosphere. But, apart from these causes, the transition of the igneous rocks from a fluid to a solid state would be attended with occasional paroxysmal movement and change. Being dependent on hydrostatic conditions for stability, the different parts of the earth's crust must extend into the great reservoir of lava to a depth in some measure proportionate to the elevation above its surface. Continents must rest on solid foundations far deeper than those which supported the body of the ocean; and the violence which subterranean forces manifested in several islands might be ascribed in part to the weakness of the barriers which restrained them. Inequalities in the solid envelope of our globe were indicated with some certainty by local forces of gravity. The anomalous character of the vibrations of the pendulum, when applied in some places, justified the conclusion that the invisible side of the earth's crust contained the greatest irregularities, and that our continental tracts of land rest on the bases of gigantic subterranean mountains, whose tops might be depressed even three or four hundred miles below the mean level of the vitrified matter. The accumulations of solid matter on the internal mountains must ultimately be crushed by the strain which their augmented size occasioned; a mighty avalanche of rock would then tumble to the thinner part of the earth's crust. Regarding these masses as the cause of earthquakes, they might account for the instantaneous manner in which the shocks of earthquakes occurred, their extreme violence and destructive character near the coasts of continents and on adjacent islands, while they were almost imperceptible in the interior of continents. It was probable that the ascending movements of silica, and perhaps of other isolated matter, might serve to bring the heavy metallic deposits from the central to the superficial regions of our planet, and the general occurrence of gold in auriferous quartz rock might thus admit of plausible explanation.

On the Red Crag Deposits of the County of Suffolk, considered in relation to the finding of Celts, in France and England, in the Drift of the Post-Pliocene Period. By W. WHINCOPP.

On the Burnley Coal-field and its Fossil Contents. *By* J. T. WILKINSON *and* J. WHITAKER.

Although of limited area, the Burnley coal-field is uncommonly rich, not only in fossil fuel, but also in organic remains. It comprises within itself a complete series of the middle and lower coal-measures. It is surrounded by ranges of hills; the principal of them being Pendle on the north, Boulsworth on the east, Gorple towards the south, and Hambleton on the west, several of them being nearly 2000 ft. above the sea-level. Geographically, the field occupies the lowest portion of the valley; but, geologically, it is the highest, when considered with reference to the stratification of the district. The most productive part of the field underlies the town of Burnley, where it assumes the form of a long trough, bounded on the east and west by two faults, running nearly parallel. The greatest depth to which the strata has been pierced occurs on the Fuledge estate, near the centre of the basin, where a depth of nearly 300 yards has been obtained. There have been found the following seams:—The Dog Hole Mine, or top bed, 6 ft. thick; Kershaw Mine, 3 ft.; Burnley Old Five-feet Mine (the main coal of the field), 5 ft.; Higher Yard Bed, 3 ft.; Lower Yard Bed, 3 ft.; Low Bottom Mine, 4 ft.; Cannel Bed, $2\frac{1}{4}$ ft.; Thin Coal Mine, $2\frac{3}{4}$ ft.; Great Mine, or King Bed, 4 ft. These are locally called "The top beds," and they include about 40 ft. of coal, imbedded in strata about 600 ft. deep. For a depth of 240 ft. below these no coal occurs. Then come the Arley series, or Habergham Mines, consisting of the following working seams:—China, about 2 ft. thick; Dandy Bed, 3 ft.; Arley, or Habergham Mines, 4 ft.: giving a total of 9 ft. of coal to about 445 ft. of intermediate strata. Strata not containing coal here again form another awkward division of the measures. The Gannister Mines follow next, comprising the Foot Mine, with a hard Gannister bed; the Spa Clough Top Bed, $2\frac{1}{2}$ ft.; Spa Clough Bottom Bed, 4 ft.; or a total of 8 ft. of coal, with 684 ft. of intervening strata. From these measures to the Rough Rock, the highest part of the Millstone-grit formation, the distance is something more than 300 ft. Omitting many seams less than 1 ft. thick, there is, from the highest mine in the Burnley measures, to the highest member of the Millstone-grit formation, a total of 50 ft. of coal, for a depth of 2025 ft. of strata. None of the thin seams in the Millstone-grit have been worked in the Burnley district. The authors describe in detail the various seams mentioned, and the fossil remains found in each. In conclusion, they state that seven large specimens of *Sigillariæ* were found in the limited space occupied by a small cotton-mill recently erected in Church Street, Burnley; and others have been found in Mill Lane during the construction of a common sewer. The whole of these were in an upright position, and several had Stigmarian roots adhering, giving the best possible evidence that they had grown and flourished on the spot. The whole of the overlying rock may be described as an immense fossil forest, occupying the central part of the Burnley coal-field; and that town itself is situated on what was one of its richest lagune jungles, replete with the flora of a former geological age.

On the Geology of Knockshigowna in Tipperary, Ireland. *By* A. B. WYNNE, *F.G.S.*

In this paper the position of Knockshigowna, a conspicuous object in the Lower Ormond part of Tipperary, was first alluded to; and the author proceeded to describe it as a somewhat ridge-shaped elevation, rising to 701 feet above the level of the sea, and 400 feet above that of the surrounding limestone plain, with a gentle slope on the south-east and a steep declivity to the north-west. Its structure was then explained, and it was stated to be formed of Silurian rocks overlaid by the Old Red Sandstone, which is unconformable to the Silurian, and is denuded at the top of the hill so as to expose these underlying rocks. The Old Red is entirely absent along the greatest part of the north-western base of the ridge, in consequence of the occurrence of a fault, by which it is buried beneath the outcrop of the Silurian rocks. The position of this fault is marked out and its existence proved by the near approach of the Carboniferous limestone and Silurian formations at two points along the line of fracture, space not being left between them for the thickness of the Old Red Sandstone as exposed upon the opposite flank of the hill.

The Silurian rocks consist of grey grits, slates, shales, flagstones, and coarse conglomerates, the latter occurring as a wide interstratified band, and taking a peculiar red colour as they approach their junction with the overlying, unconformable Old Red Sandstone. Fossils were stated to have been found by the author and W. H. Baily, Esq., F.G.S., in these Silurian rocks, and a list of them (by the latter gentleman) was given, including two corals, six kinds of trilobites, two sorts of graptolites, and twenty-five shells, belonging to the orders called Brachiopoda, Conchifera, Gasteropoda, and Cephalopoda.

From the palæontological evidence afforded by these, the rocks which contained them were supposed by Mr. Baily to belong to the lower Llandovery subdivision.

After stating the general similarity of all the rocks of Knockshigowna beneath the Old Red Sandstone as one group, and their resemblance to other Lower Silurian rocks in the south of Ireland, the discovery of the characteristic Cambrian fossil, *Oldhamia radiata*, by J. Darby, Esq., which is believed to have been found *in situ* in these rocks, was incidentally mentioned. And in conclusion, the Old Red Sandstone, carboniferous shale and limestone of the locality were each described; and the absence of the drift, except in a few places in the neighbourhood, was pointed out.

On the Excess of Water in the Region of the Earth about New Zealand: its Causes and Effects. By J. Yates, *M.A., F.R.S., F.G.S.*

The author of this memoir endeavours first to ascertain, from the best authorities, the proportion of land and water on the surface of the globe. He finds that the estimates vary between 100 land to 256 water, which is Berghaus's last estimate, and 100 land to 289 water, which is the computation of Professor Link. It is remarkable that these numbers are the squares of 10, 16, and 17, and of this circumstance the author avails himself in his subsequent arithmetical calculations.

Such being the proportion of land to water, the next question is, where to fix the centre of the water so far as it is now collected on the surface of the globe. On the authority of Berghaus, who laboured with the concurrence and advice of Humboldt and Ritter, the author assumes this centre to be 40° S. of the Equator, and on a meridian which touches upon the islands of New Zealand, although his conclusions would not be materially affected, if, following Ansted and some others, he were to fix the point 5° nearer to the south pole.

For the sake of simplicity and clearness in computation, he supposes all the water to be collected around its centre in a uniform mass, instead of being distributed and ramified into oceans, seas, bays, and straits. Thus a small circle divides the entire mass of land from the entire mass of water. This circle is delineated on the globe by taking the centre of the land and drawing a circle round it with 62° 30′ as radius, this radius being assumed on the supposition that it is safest to take a mean between the two extreme proportions of land and water.

In addition to these data respecting the proportions and the centres of the land and water, the author shows that the mountains in the so-called Land Hemisphere greatly surpass in elevation those of the Water Hemisphere; and presuming that the mountains in the Water Hemisphere are the highest points of submerged continents, he uses the mountains of the Land Hemisphere as gauges for measuring the general depth of the water, which he finds to be nearly two kilometres. By a subsequent investigation he finds the general elevation of the continents above the level of the water to be about one-third of this quantity.

To explain his theory the author employs a diagram, which is a section of the earth through the meridian of New Zealand. A diameter is drawn from the centre of the ocean and is intersected by a perpendicular, which is the chord of the before-mentioned arc of 125°, and which divides the collected land from the collected water. By the use of this diagram, and proceeding from one step of mathematical reasoning to another, having likewise assumed that the hemisphere of the solid earth contiguous to the great mass of water is heavier than the other hemisphere, and that the solid earth has consequently a centre of gravity lying to the south-eastward of its centre of magnitude, the author computes the distance between these two centres to be about 1260 metres. From this apparent fact, coupled with the general permanency of the surface of the terraqueous globe, he infers that the interior of the globe must be in the main solid, and of this he further avails himself to explain the phenomena of earthquakes and the so-called "magnetic storms."

ZOOLOGY AND BOTANY.

THE CHAIRMAN (Professor Babington), in opening the Meeting, made some remarks on the advantages of meetings like those of this Association. The great object of science was the unfolding the laws by which the universe was governed, and one of the greatest encouragements to this study was the assembling together of men of kindred minds and similar pursuits. Sometimes difference of opinion engendered feelings of an unpleasant kind, which personal intercourse served to remove; and thus these meetings, on account of their scientific and social value, had become increasingly appreciated.

On some Points in the Anatomy of Cypræa. *By* T. ALCOCK, *M.D.*

Examinations of numerous specimens of *Cypræa*, received from the Smithsonian Institution, have led me to the conclusion that the oral organ in this genus is a rostrum, capable, however, of complete retraction. The food found in the stomach of the animals consists almost entirely of sponge. The teeth differ considerably from one another in different species, but all have the essential characters of those of the Rostrifera.

The gills are two in number: one large, semicircular, and pectinate; the other trefoil-shaped and plume-like. The whole roof of the branchial chamber behind the gills is occupied by a very large mucus-gland.

On the Cosmopolitan Operations of the Smithsonian Institution. By PHILIP P. CARPENTER, *B.A., Ph.D.*

An account is given of this Institution at page 109 of the last volume of 'Transactions.' At a time when political convulsions are throwing such great impediments in the way of Transatlantic science, it is satisfactory to know that it is only in pecuniary resources that its operations have received a check. The U.S. Government are simply the trustees of the fund, not its owners; and the stores of scientific material are equally available for students in all parts of the world. The policy has been inaugurated of always depositing the first duplicate of type specimens on the other side of the Atlantic. The accumulation of a large museum at Washington is not the object of the Directors, but rather the distribution of the duplicate materials, wherever it can be shown that they will promote the "increase and diffusion of knowledge among men."

On the Variations of Tecturella grandis. *By* PHILIP P. CARPENTER, *B.A., Ph.D.*

Of the score of so-called species of Acmæidæ described from the Californian coast, there are seven which are tolerably well established. The species of *Acmæa*, however, run into each other by so many intermediate forms that their determination is very difficult. The amount of variation of which one species is susceptible is well shown in *Tecturella grandis*, which presents well-marked characters to separate it from all other species of limpets; and yet, in about thirty specimens examined, the ratio of the anterior portion in front of the apex to the entire length (generally a constant quantity in each species) was found to vary from 1:7 to 1:20. In this, as in similar cases, the facts should be tested both by the Darwinian theory and by the theory of specific permanence. It is not to be expected, in the present state of our knowledge, that either theory alone will afford a satisfactory explanation of all the facts as they arise.

On the Anatomy of Orthagoriscus Mola, *the short Sunfish.* *By* John Cleland, *M.D.*

The integument of this fish is a dense substance of great thickness, consisting of felted fibres, whose meshes are filled with a copious jelly-like matter containing cells. There are imbedded in it, on the front of the head and in common with the caudal fin rays, hard plates presenting a peculiar structure, composed of intercommunicating tubes, which contain masses of crystalline matter, and lie in a hyaline matrix.

The skeleton can only be studied in the recent state, on account of important masses of cartilage entering into its structure. There are no ribs. The interspinous bones of the long and pointed dorsal and anal fins are of great size; those of the caudal fin are crowded between the last osseous vertebra and the superior and inferior spines of the vertebra preceding. Every fin-ray is composed of a pair of osseous slips, arising one on each side of a cartilaginous basis. Those of the dorsal as well as those of the anal fin are crowded together into a compact mass, which moves in a groove on a large block of cartilage into which the interspinous bones are inserted. The caudal fin rays are isolated from one another, each imbedded separately in the integument; their cartilaginous bases are short and thick; and in a line with them is a similar cartilage without any fin-ray attached, which is apparently vertebral in its nature, but which is placed, not in direct continuation with the last osseous vertebra, but on a slightly higher level, reminding one of the upward tendency exhibited by the last vertebra of most osseous fishes.

The muscular masses on each side of the body consist entirely, as was pointed out by Mr. Goodsir, of immensely developed fin-muscles.

The abdominal cavity lies in immediate contact with the integument, there being only two very small vestiges of abdominal muscles. The vertebral column, therefore, is not used as an instrument of motion, but only supports the dorsal and anal fins, which, together with the short tail, are the organs of progression.

As was pointed out by Arsaky, the spinal cord of the Sunfish is extremely short, and terminates within the cranial cavity. The spinal canal is occupied by a large cauda equina. The nerves, after emerging from the spinal canal, are joined together by a communicating cord and ganglia.

As if to compensate for the want of muscular parietes to the abdomen, the intestines have very thick muscular coats. They are coiled closely together into a mass, which is tightly invested by a single fold of peritoneum, and the spaces between the coils are entirely occupied by large lymphatic sinuses.

There is a marked circular fold of the mucous membrane a few inches above the rectum, which may be considered as a rudimentary cæcum.

The heart presents eleven semilunar valves: three protect the entrances of veins into the auricle; four guard the auriculo-ventricular opening; and other four, two of them very small, the bulbus arteriosus.

The ear has no otoliths, and only two semicircular canals. The nostrils are extremely small. The eye is very large.

A number of other peculiarities, relating to the bones of the head and to the viscera, were pointed out.

This paper is published in full in the Nat. Hist. Review, April 1862.

A Scheme to induce the Mercantile Marine to assist in the Advancement of Science by the intelligent Collection of Objects of Natural History from all parts of the Globe. By Cuthbert Collingwood, *M.B., M.A., F.L.S., Liverpool.*

The British Association at Manchester had appointed a committee to report upon the subject, and requested him to take the direction of it. It consisted of the following gentlemen:—Dr. Collingwood, Liverpool; John Lubbock, F.R.S., London; R. Patterson, F.R.S., Belfast; J. Aspinall Turner, M.P., Manchester; Rev. P. P. Carpenter, Ph.D., Warrington; and the Rev. H. H. Higgins, M.A., Liverpool.

The mercantile marine of Liverpool, engaged in foreign and colonial trade, amounting to 4500 sail, measuring $2\frac{1}{2}$ millions of tons, and employing many thousands of men, exhibits an amount of enterprise such as probably no other age and no other place has ever before shown. The whole globe is scoured by these men and ships, in search of whatever may conduce to civilization and to the wealth of the country which is the centre of this vast and important combination. Nor is the port of Liverpool, although the largest (representing one-third of the commerce of England), the only one to which a similar remark is applicable; and it therefore becomes a question worthy of consideration—How is it that such a vast staff of enterprising men, constantly sailing to all parts of the globe, do so little to add to our knowledge of the natural productions, which they, of all men, are in the best position to explore and to provide for the investigations of scientific naturalists at home? Why do these men, confining their attention to the immediately useful results of the trade in which they are engaged, altogether pass by natural objects, the collection of which could not fail to be a source of interest, and which, to men with a moderate degree of education, would, it might be imagined, afford the stimulus of a rational pride? One thing is certain, namely, that no accessions of importance are derived to our museums and collections from the labours of seafaring men. A piece of coral, a shell or two, or something which has received attention from its oddity, is occasionally brought by the sailor from the rich and interesting regions which he has visited; but, as a general rule, anything of value or importance is not even to be looked for. There are, however, a few, a very few, honourable exceptions, in men whose intelligence leads them to see the value of the opportunities they enjoy, and to make use of them, as far as in them lies, for the improvement and advancement of knowledge. But the willingness of these gentlemen to render their assistance in any direction in which their scientific friends ashore point out that they can be useful, only serves to place in the strongest possible light the immense value which would accrue to science were a large body of such men, instead of one or two, constantly employing themselves in a similar manner. We cannot expect all captains of vessels, or, indeed, perhaps any, to use in this direction the intelligence of a Darwin or a Huxley; but it is not, perhaps, too much to look for that they should exercise a moderate degree of interest in the acquisition of rudimentary information, and a certain amount of capacity in the selection and collection of the multifarious objects which daily come under their notice. The difficulties which are uniformly brought forward against the idea of seamen turning their attention to natural history are chiefly on the score of want of time to attend to anything except their own business. But those who are best competent to judge give a different account. They tell us, indeed, that the seaman, during his passage through subordinate grades, has his hands full, and his attention fully occupied by his ship duties. But when he is entrusted with a command, the case is different. He is no longer a servant on board his vessel, but a master. His life of active employment is changed for one of *comparative* idleness, and it is well if the time thus left on his hands is not put to an evil use. Sailors have not the advantages which the mechanic enjoys upon shore. None of the ordinary rational modes of spending his hours of leisure are open to him. He is dependent upon himself for amusement, and this is more particularly the case with the captain. How often, unfortunately, do we hear of captains of vessels being charged with intemperance, cruelty, and the long train of evils resulting from an unoccupied mind, and an absence of sufficient employment for the energies of mind and body. The ship is not *always* in a gale—she does not *always* require the close supervision which is doubtless often necessary. There are abundant seasons of repose, and ample time which might be employed in the pursuit of those rational amusements or studies which would be of so vast a benefit to science. Again, a captain naturally feels that, should he devote any attention to natural history, he may lay himself open to the charge of neglecting his ship's duties. His owner may possibly be narrow-minded enough to condemn him for allowing anything to occupy his mind besides the routine of his ship work; or he may even be shortsighted enough to imagine that a man with an object in his moments of leisure is less fitted to occupy a place of trust than a mere machine who has no idea beyond the mechanical duties of his profession. And not without reason has the seaman this fear—a fear which, I know, weighs considerably with conscientious captains, who would, if they received the sanction of their owners, do great service to science, without abating one jot of their vigilance and activity in their primary duties. The main point, then, to be considered is—how shipowners generally can be induced to sanction in their masters the cultivation of those tastes which they often possess, and which cannot but have a beneficial effect upon their character, and the improvement of those opportunities which they so abundantly enjoy. This is the great desideratum, and until this is done, no great good can be effected. The ship-captain of intelligence must know that his attention to natural history, or any other branch of science not immediately connected with ship duties, is not only *not* looked upon with suspicion by his owner, but is *encouraged* by him. He must feel that his master regards his scientific studies and attainments, not as unfitting him for command and full confidence in the management of the important interests entrusted to him, but as absolutely rendering him more trustworthy, on the principle enunciated by a well-known member of the mercantile marine service, that "a man with a hobby is always safer both at sea and on shore than a thoroughly idle man." The advantages which might be expected to accrue from such a plan are manifold. Museums such as those of Liverpool and Manchester should not lack specimens in any department, with such a staff of industrious and intelligent collectors constantly bringing contributions. But by no means the least important result would be the elevation of the mercantile marine service as a body, and their emancipation from the evils too often looked upon as inseparable from their habits of life, by giving them a rational object upon which they may expend their energies, when not called upon by pressing duties on board ship. They have no resources such as those possess whose life is passed on shore, and it cannot be otherwise than that, herding together, as they do, for months at a time, with scarce any of the amenities of life, their minds should degenerate to a dull blank, or even to a worse condition; and it too often happens that in this respect the captain is in no degree superior to his crew. Regarded, therefore, from a philanthropic point of view, it is a subject worth inquiring into, whether or not some scheme may be rendered feasible by which this opprobrium may be removed. No shipowner will deny that such an amelioration of the seaman's character would be ultimately followed with advantage to his own personal interest; but that advantage is not to be reaped suddenly, and it is too distant in its prospect to offer much inducement to take much trouble to accomplish it. The direction which I have here supposed the ship-captain's energies to take is, however, by no means the only one which may be followed with usefulness and advantage. I have made it prominent because I believe it would, in a vast number of instances, be adopted with most useful results. But men's tastes, doubtless, differ considerably, and the study of natural history would not commend itself to all. Various subjects of study might be followed out advantageously, and the sciences of navigation, meteorology, &c. would receive important accession from the intelligence which a higher standard of education would develope among our mercantile marine. Some stimulus, however, would undoubtedly be needed to carry on this work; and the nature of the rewards which might be offered to induce the cooperation of seamen should occupy our careful attention and consideration. Among the commanders of the mercantile marine there are many intelligent men, who would gladly embrace the opportunity, if it were offered to them, of distinguishing themselves in the walks of science, and raising themselves above the level to which they are at present doomed. Whether this stimulus should be in the way of honorary certificates, pecuniary or honorary rewards, association with scientific bodies already in existence, or of any other kind, would be an important matter for after consideration. I have said, however, enough to bring the matter fairly before you, and in your hands I now leave it, hoping it may not be permitted to fall to the ground, but may be taken up by the influential members of the Association connected either with science or with commerce, my own humble cooperation being always at their service.

On the Culture of the Vine in the Open Air. *By* J. Couburn.

On Barragudo Cotton from the Plains of the Amazon, and on the Flax-fibre Cotton of North America. *By* W. Danson, *of Liverpool.*

The writer states that he has known the vegetable substance called Barragudo cotton for more than twenty years, a small import having been received from Peru *viâ* Cape Horn about that time. It was represented as the produce of a very large tree, 30 feet to 40 feet high, and the cotton, when ripe, hangs down to the ground by its own fibres connected. Yet the consumers state it will not spin—a customary objection to anything new. More recently a similar import (about half a dozen bags of 70 lbs. each) came from the River Plate *viâ* Pernambuco. Any quantity can be had from the east side of the Andes and the plains of the Amazon. As to the staple of the cotton, it is very silky and short; but by grafting, or superior technical cultivation known to naturalists, it might no doubt be improved. Large quantities must be brought to market, and then machinery will be altered to suit its working, as was the case with alpaca, which has a silky fibre. He sold one bag of the Barrugudo cotton at 3*d.* per lb.; but, as the Yorkshire buyer did not accept delivery, the whole of the last lot was taken by the importer for stuffing sofa cushions and mixing in feather beds, instead of purchasing swandown at 12*s.* 6*d.* per lb. Here is a large field for the use of such fibres; and if brought to this country in large quantities, it must be mixed with cotton, like Mingo or devil's dust, or be spun up with sheep's wool. Through the kindness of Mr. M. J. Whitty, of the 'Liverpool Daily Post,' the writer was authorized to exhibit a sample of new fibre from the wild flax of North America. Millions of bales, he states, can be obtained at a cost of less than 4*d.* per lb., so profusely does the wild flax exist. These new fields ought to command attention when there is so much anxiety to increase the supply of cotton. The author contends that six million acres of land in Ireland can be had at a nominal rent, on which good cotton can be grown, the land never having been grazed, scratched, or nibbled by cattle.

On the Functions discharged by the Roots of Plants; and on a Violet peculiar to the Calamine Rocks in the neighbourhood of Aix-la-Chapelle. By Professor Daubeny, *LL.D., M.D., F.R.S.*

This violet, although its petals are of a uniformly yellow colour so long as the roots are in contact with the zinc, seems to be a mere variety of the common *Viola lutea*, which has purple petals when it grows on ordinary soil; and accordingly, on the confines of the two strata, the petals of the plant are partly yellow and partly purple. The author made some further remarks upon the absorption of mineral bodies by the roots of plants, and in conclusion gave it as his opinion, that the selective power possessed by them indicated a force independent of any physical cause, and which he therefore regarded as of vital origin.

On the Influence exerted by Light on the Function of Plants. By Professor Daubeny, *LL.D., M.D., F.R.S.*

The author referred to certain principles established by him in a paper published in the 'Philosophical Transactions' for the year 1836, in which it was laid down, first, that the decomposition of carbonic acid and the consequent disengagement of oxygen was influenced by the luminous rays of the spectrum, and not by the calorific or actinic ones; secondly, that under particular circumstances nitrogen is emitted during sunlight from the leaves of plants; and thirdly, that other functions of plants, such as the greenness which the leaves assume, the peculiar property which belongs to certain ones, as to the sensitive plant, of collapsing on the application of stimuli, the exhalation of water from the leaves and its absorption by the roots, are probably dependent upon the same influence.

On the Method of Mr. Darwin *in his Treatise on the Origin of Species. By* H. Fawcett, *M.A.*

He said that, as he could not conform to what he believed was the rule, that communications should be read (Mr. Fawcett being blind), he would promise to keep as close to his subject as though he had written his paper. The title which he originally fixed upon was, "That the method of investigation pursued by Mr. Darwin, in his Treatise on the Origin of Species, is in strict accordance with the principles of logic." He feared that he might be charged with presumption in attempting to say anything on Mr. Darwin's great work, which had already engaged the attention of the most accomplished naturalists of the day. He had been assured that the discussion on the subject at the last Meeting of the Association had never been surpassed in the interest it excited or in the talent which it called forth. Indeed, the work had divided the scientific world into two great sections; Darwinite and anti-Darwinite were almost the badges of opposite parties. Professor Owen, Professor Sedgwick, and Mr. Hopkins had given to the new theory a decided opposition; Sir Charles Lyell, Professor Huxley, and Dr. Hooker had given to it a support more or less decided. All who took an interest in the subject had a right to inquire whether the theory—whatever might be thought of its details—had been logically brought forward. The province of logic was not to discover new facts, but to decide whether facts were legitimately used to establish that which it was pretended they proved. It was constantly alleged that Mr. Darwin was illogical; that he had not followed the Baconian method. The 'Quarterly Review' assured us that Mr. Darwin had not followed in the steps of Newton and of Kepler; but nothing was more easy than to make such charges, which often only concealed pretentious assumptions of scientific knowledge. It was more pertinent to inquire—What is the method of solution of which such a problem admits? He insisted that if ever solved it could only be by a method analogous to that attempted by Mr. Darwin. It could only be solved in this way:—An hypothesis, resting upon more or less perfect induction, must be started; from that hypothesis certain deductions must be drawn; these deductions must be tried, by seeing whether they would explain the phenomena of nature, and they must be verified by seeing whether they agreed with what can be observed in nature. If this explanation and verification was complete, the hypothesis was advanced from an unproved to the position of a proved and established theory. The Bishop of Oxford last year said that the theory was so absurd that no scientific man could for a moment think that it was in any degree worth considering. But Dr. Hooker, than whom a more eminent authority could not be quoted, at once disposed of the Bishop by saying, that as he believed the theory worth considering, he ought to "apologise for addressing the meeting as a man of no scientific authority." Dr. Hooker added that he knew of the theory five years before; that, at first, no one more opposed it; but five years' devotion to natural history had convinced him that the theory was worthy of the most careful consideration and examination. Mr. Darwin, with the most perfect candour, explained in his work that his theory did not yet explain all the facts of nature; but it must not be supposed that his twenty years' labour had done nothing to advance the ends of science. Mr. Darwin had strictly followed the rules of the deductive method as laid down by John Stewart Mill. When Kepler inferred his law of the connexion between the major axis of the planets and the times of their revolution, he so inferred from observation, which he could strictly verify by mathematical calculation. The origin of species does not admit of such a verification. In chemistry there was much more power of proof or verification by experiment than was possible in physiology; so with other sciences. When laws of nature cannot be discovered by experiment, we are obliged to go to deductive reasoning. Newton had only an hypothesis, and not a theory, as to the law of gravitation; the law he first tried was an incorrect one. He tried again; and then, as Professor Whewell said, by a tentative process he discovered the correct law. Mr. Darwin had told him (the speaker) that his hypothesis was not at once suggested to him. He found in his studies that there was something wanted to explain many of the observed phenomena; years passed, and at length his hypothesis was very indirectly suggested—for he said that it came from reading Malthus's 'Essay on Population.' Twenty years of unremitting labour he had devoted to the endeavour to verify the conclusions which might be deduced from this hypothesis by the facts observable in nature. He believed that Mr. Darwin's second work, for which the author had accumulated a great mass of knowledge, would prove beyond doubt that no one could have been a more conscientious or laborious observer than he had been. Newton could verify his hypothesis by the simplest experiment—he had but to drop a stone from a tower and to note the time occupied in its descent. But the problem of the origin of species is concerned with an epoch of time associated with geological epochs; therefore experiment could only be made during so short a time, that nothing more could be obtained than an argument resting on a, comparatively speaking, unsatisfactory analogy. Darwin had been able to show that by a system of artificial natural selection two organisms, originally descending from the same form, could be made to differ so much, that if they were found as fossils they would undoubtedly be classed as distinct species; and, therefore, how a morphological species could be produced. But his experiments had failed to show how a physiological species could be produced; for no one could show that two varieties from the same form could be made to differ so much that they would possess the quality of infertility. This was too often forgotten by objectors. The Egyptian sculptures were pointed to to prove that during 3000 years the causes looked to by Darwin had done nothing to alter the form of animals. But what would be said to him who, by discovering that 3000 years ago Mont Blanc was of the same altitude as now, should think that he had thus disposed of the theories of modern geology, that the stupendous peaks of Switzerland were lifted from their ocean bed, and that every change on the surface of the earth had been produced by an indefinite continuation of physical causes which are in ceaseless operation? Mr. Darwin admitted that geology did not show that in animal life there had been those transitional links that ought to exist according to his theory, and according to any other of gradual transmutation. He (the author) could not see that this theory detracted one iota from any of the attributes of the Creator. If we suppose that the introduction of every new species required a distinctive act of creative will, then, of course, the Creator must have interposed every time a new species was introduced. But, if we supposed that every living organism has descended from those forms in which life was first placed upon this planet, it does not in the slightest degree dispense with the necessity of supposing that life could only first be so placed by the act of Omnipotent Creative Will. It was a favourite illustration in religious works, the discovery of Newton which explains how planetary motions are produced; and he (Mr. Fawcett) believed that if ever the day came when the origin of species should be explained in fulness and simplicity, he who so explained it would be considered not only to have advanced science, but to have conferred a benefit upon religion. The attackers of Darwin forget that he has not attempted to displace a theory received as right, but merely to throw some light where all before was dark. We should, therefore, be all the more ready to welcome the conscientious labours of one who like Mr. Darwin had unremittingly devoted himself to explain to some extent what had been aptly termed the "mystery of mysteries."

On the Arrest of Puparial Metamorphosis of Vanessa Antiopa *or Camberwell Beauty. By* George D. Gibb, *M.D., M.A., F.G.S.*

After making a few remarks upon deformities and arrest of development amongst the insect tribe, the author proceeded to describe some examples occurring in the *Vanessa Antiopa*, which were exhibited to the Section. Of twenty-eight specimens which he had obtained in the month of July, all underwent complete metamorphosis, with three exceptions. These to some extent illustrated the progress of the process of emersion of the imago from the pupa-case.

In the first specimen, the first stage of emersion was accomplished, *i. e.* a part of the wings had protruded from each lateral fissure throughout its whole length to the extent of $\frac{3}{16}$ths of an inch, permitting a view of the anterior part of the thorax. Metamorphosis then became arrested, and existence terminated.

In the second example emersion was more advanced; the left wings had emerged a $\frac{1}{4}$ of an inch only, whilst the right almost wholly protruded, but remained in contact with one another. The puparial case is on the point of freedom, and the lower part of its abdominal segment is empty. Here further metamorphosis became arrested, and life ceased.

In the third, emersion was complete; metamorphosis, however, was not so, and it was associated with malformation. The right anterior wing was fully expanded, whilst the posterior was crumpled up. The left anterior wing was almost wholly wanting; a mere rudimentary appendage existed two lines long. The left posterior wing was only partly expanded posteriorly, the remainder being crumpled up.

The author entered into the probable causes of these arrests of change and development, and believed that they did not depend upon injury, from the care taken when the chrysalides were first collected.

On the Height of the Gorilla: a Letter from Dr. J. E. Gray, *F.R.S.*

Much difference occurs in the statements of travellers and others with reference to the height of the great African ape. Bowdich, the first traveller by whom it was mentioned, under the name of the *Ingeña*, states it, on the authority of the natives of the Gaboon, to be generally 5 feet high; but in some recent notices it has been asserted to reach the height of 6 feet 2 inches; and the specimen exhibited at the meeting of German naturalists at Vienna is said, on good authority, to have measured more than 6 feet in height. The measurement of a stuffed skin without bones is necessarily delusive, depending as it does, first, on the mode in which the skin has been originally prepared, and, secondly, on the extent to which the artist may be disposed to stretch it. Such measurements are not to be relied on unless they are in accordance with those of the bony skeleton; and it therefore occurred to me that it would be desirable to measure the long bones of the limbs of the different skeletons existing in the British Museum, the osseous structure giving the only certain dimensions on which reliance can be placed. The skeletons in the British Museum are six in number, viz.—1. A skeleton, obtained from Paris by Prof. Owen, and mounted in the best French manner. 2, 3, 4. Skeletons of male, female and young, purchased from M. Du Chaillu. 5. A skeleton of a male, purchased at Bristol, of which we have also the stuffed skin. 6. An imperfect skeleton, purchased from M. Parzudaki, of Paris. The measurements of the several bones of each of these skeletons are given in the following Table:—

	Humerus.	Ulna.	Radius.	Femur.	Tibia.	Fibula.
	Measurement in inches.					
Articulated specimen from Paris	17	14	13	$14\frac{1}{2}$	$11\frac{1}{2}$	$10\frac{1}{2}$
Skeleton from Du Chaillu's stuffed specimen (called the "King of the Gorillas")	$16\frac{1}{4}$	14	$13\frac{1}{4}$	$13\frac{3}{4}$	11	$9\frac{3}{4}$
Skeleton of young male, from the specimen purchased at Bristol.................	$14\frac{1}{2}$	..	11	15	..	$9\frac{1}{2}$
Imperfect skeleton, purchased of M. Parzudaki	12	11	10	11	..	$9\frac{1}{2}$
Skeleton of female, purchased of M. Du Chaillu	13	11	$10\frac{1}{2}$	11	9	7
Skeleton of young male, purchased of M. Du Chaillu	12	$11\frac{1}{2}$	$9\frac{1}{2}$	10	$8\frac{1}{2}$	7

They were taken by Mr. Gerrard with a tape measuring inches and quarters of inches only, but are quite sufficient for a comparison between the specimens themselves, and as affording materials for determining the actual height of the animal. As the largest of these (viz. the Paris specimen, photographed for the Trustees of the British Museum by Mr. Fenton) stands 5 feet 2 inches in height, we are justified in concluding that to be in all probability the extreme natural height of the full-grown animal.

A letter was read from Dr. Gray, of the British Museum (dated Sept. 6, 1861), to Professor Babington, in reference to Professor Owen's paper on the Gorilla, in which it was stated that the skin of the great Gorilla, now in the British Museum, exhibits two opposite wounds, the smaller in front of the left side of the chest, the larger close to the lower part of the right blade bone. Two of the ribs in the skeleton of this animal are broken on the right side, near where the charge has passed through the skin in its course outwards. Dr. Gray and other naturalists having examined the specimen, found two holes in the nape of the neck (now filled with putty); there are also two large holes in the thin portion of the hinder part of the skull belonging to the same skin which pass through the bone, and are quite sufficient to have caused death. In neither skin nor skeleton is there any evidence of a gun-shot entering on the left side of the chest; and the fracture of three (not of two) ribs on the right side, and the supposed corresponding rent in the skin, are so utterly unlike the effects of a gun-shot, that no sportsman could possibly so consider them.

On the Flora of Manchester. *By* L. H. Grindon.

After some observations on the climate and soil of Manchester, the author remarked:—"The positive character of the Manchester Flora consists in the presence or 370 or 380 British plants, which are indifferent to the soil they grow upon, and which clay and sandstone suit as well as any other. These are, of course, the common plants of the country in general; and were it not that the peat-bogs furnish many species peculiar to such habitats, and that the low level of the country and the abundance of moisture combine to the production of innumerable marshy hollows, in which plants are found plentifully that the limestone districts afford penuriously or not at all—were it not for these, the Manchester Flora would be no more than a list of cosmopolites. The ponds of the district, locally called 'pits,' are innumerable. In Cheshire they often become enlarged into beautiful sheets of water, called 'meres,' which greatly enhance the picturesque character of the northern parts of that county. South-east Lancashire contributes also a peculiar class of habitats in its innumerable and very pretty little winding ravines, locally called 'cloughs,' the sides clothed with trees, and a stream running along the bottom. These, like the marshy hollows, supply many plants in great abundance that districts more favoured in soil and climate fail to offer, and, along with the peat-mosses, supply the principal part of what is locally interesting. Of rare and extraordinary plants we do not possess a single instance, except when they appear, as in other places, adventitiously. We have no permanent treasures or rarities, such as give celebrity to St. Vincent's Rocks, the Great Ormshead, and the Scotch mountains. If a claim to such a character can be asserted by any of our plants, that claim must come from *Carex elongata.*" In conclusion, he noticed some of the more remarkable and conspicuous plants of the district. He added that, on a review of the whole subject, it appears that the Manchester district, although exposed to some great disadvantages, is quite as productive of interesting plants as any other. They are fewer in number and they are less brilliant in appearance; nevertheless the botanist who would wish to enjoy himself, and to find everything necessary to intimate acquaintance with the types of the British Flora, needs not to distress himself at the seeming dearth of Manchester. If he will seek he will find, his reward augmenting in the ratio of his philosophy.

On the Arrangement of Hardy Herbaceous Plants adopted in the Botanic Gardens, Liverpool. *By the* Rev. H. H. Higgins.

On the Development of the Hydroid Polyps, Clavatella *and* Stauridia, *with Remarks on the Relation between the Polyp and its Medusoid, and between the Polyp and the Medusa.* *By the* Rev. T. Hincks, *B.A.*

The author, after describing the characters of the Medusoid of *Clavatella,* and comparing it with *Stauridia,* went into the question of whether the polyp, or stock which bore the medusoids, or the medusoid itself, which bore the eggs, should be regarded as the perfect animal. Quatrefages and others regarded the medusoid as the perfect form; but the author was inclined to recognize the medusoid-bearing individual (the stock) as the perfect animal.

On the Ovicells of the Polyzoa, with reference to the Views of Prof. Huxley. *By the* Rev. T. Hincks, *B.A.*

In this paper the author gave the results of his study of the Polyzoan ovicells, and showed, in opposition to the view of Professor Huxley, that these organs are not "marsupial pouches" into which the ova pass to complete their development. Repeated observations had convinced him that the ovum, which was ultimately developed into the ciliated embryo, was produced *within the ovicell,* in an ovarian sac, which buds from the endocyst at the upper extremity of the capsule. This sac, from its first differentiation, might be detected without difficulty. There were also ova which were produced within the *cells*. These were never ciliated, and only escaped after the death of the polypide. Their history required further investigation.

The Rev. A. Riky Hogan, M.A., exhibited living specimens of *Niphargus fontanus* taken by himself at Puddletown, near Dorchester, from the water of a pump. A paper on the subject of this and allied species had been read by Mr. Hogan at the Meeting of the British Association held at Oxford, but these Crustacea were not before exhibited alive.

On Daphnia Schæfferi, *with a Diagram. By the* Rev. A. R. Hogan, *M.A.*

So few observers have paid any attention to the family to which this little animal belongs that any fresh notes on its habits or economy are acceptable. In common with several other allied Entomostraca, *Daphnia Schæfferi* bears the English name of "Water-flea," and German of "Wasserfloh;" but I have not been able to discover any peculiar suitability in the appellation, there being nothing in common between it and its terrestrial namesake, except restlessness.

Professor Ehrenberg's celebrated discovery of the corneous integuments of Entomostraca, which occur in millions in some of the rocks of Germany, well illustrates the important part assigned to these creatures on our globe. My first acquaintance with the species of which this paper is the subject was made at Shaftesbury in Dorsetshire, where they are found abundantly in the water artificially supplied to the town for drinking purposes. On the 13th of February, 1861, I received six apparently full-grown specimens; these I placed in a vessel which admitted of my observing their reproduction and subsequent development. Within a day or two afterwards, the water in which the *D. Schæfferi* were placed appeared to swarm with young, exceedingly minute, yet visible not only in the water, but also within the parents' shelly integuments, where, through the semitransparent valves, they might easily be seen moving about, and seemingly trying to effect an exit. Those which had already escaped were all performing the same curious gyrations which distinguish the mature individuals. It is the habit of these creatures to keep unceasingly swimming round and round in a vertical circle, and no one who has ever seen it can avoid being struck with its gracefulness. Whenever they wish to change the locality of their revolutions, they swim by sudden and rapid jerks, but in a direct line, to another place, and then recommence wheeling up and down. Sometimes, however, they rest from motion entirely.

Eight weeks after the birth of their young, all the original Daphniæ were dead, but the former had not yet attained more than half their size, nor shown any signs of reproduction. At this time I had about thirty-five specimens. But another six weeks sufficed to bring about the complete transformation; and after seeing them for the last time cast their exuviæ, I had the satisfaction of observing that the full size of the original specimens was in some instances attained, and some young again produced. They were, however, not at all so prolific as those which had been captured full-grown; and as the whole life of the Daphniæ had passed under review, I did not care to retain them longer alive, but placed the bred specimens, which had already reached maturity, in alcohol for exhibition to the Association.

Further observation will no doubt reveal many more details of interest regarding these animals.

Extracts from a letter from Professor Huxley to Dr. Rolleston, in reference to the brains of the Quadrumana, were read by Dr. Rolleston.

On an Abnormal Form of Cyathina Smithii.
By J. Gwyn Jeffreys, *F.R.S., F.G.S.*

Mr. Jeffreys exhibited specimens of *Cyathina Smithii*, which he had dredged at a depth of nearly 90 fathoms in sandy ground, about 25 miles N.E. of the Unst lighthouse in Zetland. The peculiarity of the specimens consisted in their being inversely conical, instead of their having the usual form of that coral, which is cylindrical, and this appeared to be owing to their having been attached to cases of the *Pomatocerus arietinus* (sometimes called *Ditrupa subulata*), a *Dentalium*-like Annelid. One specimen was attached to a perfect case, others adhered to fragments of cases, while the rest bore no trace of attachment and were quite free. In the last-mentioned state they appeared to agree with a drawing and description given by Dr. Johnston, in his admirable work on British Zoophytes, of a specimen received by him from Professor Edward Forbes, who considered it to be the *Turbinolia borealis* of Dr. Fleming. The specimens now exhibited had much the aspect of *Turbinoliæ* or *Sphænotrochi*. *Cyathina Smithii* is not uncommon in the same seas where these specimens were obtained, but at a less depth than is above stated, and its usual habitat is on rocks and stones, to which it is permanently attached by its entire base. The explanation offered by Mr. Jeffreys for the abnormal form of his specimens is, that they had attached themselves to empty cases of the *Pomatocerus*, being the only hard and stationary substances they could find in their unusual habitat (sand), and that when these cases were broken off, the base of the corals became rounded by attrition against the sand, and they thus assumed their present shape. The first-formed layers, which constitute the base of the coral, are soon deserted by the animal; and there appear to be no means of repairing any injury to that part, much less of the coral reaffixing itself to another prop. Specimens of *Cyathina* sometimes have also a very narrow base when they are attached to other corals. Mr. Jeffreys observed, that the peculiarity in question appeared to be the result of a well-known law, or inherent principle of organization, by which a change of external conditions influences to a certain extent the form of animals and plants, and that such modification of form is not due to what has been called "natural selection."

Absorbing Power of the Roots of Plants. *By* Dr. Jessen.

Dr. Daubeny had established that different species of plants, growing in the same soil, take up therefrom different foods, and contain minerals in different proportions. This selection, it will be said, is made through "vital force"—a convenient phrase for hiding anything that you cannot or have not inquired into. If we went down to the elementary composition of the living body, the term might be defined as meaning the formation and combination of cells. In this sense it corresponds with, and has comparatively the same range as, the term "crystallizing force" as regards minerals. The force that puts together crystals and that which puts together cells and forms them into living bodies, is equally an unknown force; we use for each the term mentioned. Taking "vital force" to mean the formation and combination of cells, the secretive power of plants was thence to be explained. Some ancient philosophers held that plants desired and selected food nearly in the same way as animals. That opinion was long ago given up; but where is the difference between animals and plants? Men and animals move to food that they want; plants grow for it. This was a point too often overlooked. But animals can move away or cease to take food when satisfied; plants advance their roots amongst their food, and they cannot use the same parts of the same root for obtaining that food a second time. They have, so to speak, to throw out new fibres every time they want food. A sound rootlet took up fluid, whether nutritive or not, in a manner different from an injured one; and many physiologists and nearly all chemists have experimented on wounded plants, without knowing it, owing to the delicate handling which rootlets require. The absorption goes on by endosmosis through the bark-cells. Dr. Graham says that by every such process the membrane of these cells is thinned and dissolved; that the endosmosis is different for every different membrane; and that the force of endosmosis is altered not only by the different nature of the substances going into the cell, but also by the nature of the sap in the cell itself. The author considers these facts, as made out by Mr. Graham, to be the starting-point of a new era in the physiology of nutrition. No one has yet taken up the matter and pointed out the value of these discoveries; and it was sufficient at present to point out that Dr. Graham shows that any slight difference in the composition of the membrane, or of the contents of a cell, will be a sufficient cause for a decided difference in the nature of the food introduced into it. The point of a rootlet is of a very different structure from its upper part. It serves only for the growing out of the rootlet, whose cells are ormed in the upper part. Many of the cells run into short hollow hairs, which, like the cells, have a very thin membrane. The fluid taken in by the rootlet after a time destroys the outer layer of cells, and the second layer comes into play; but the constant production of new cells in the interior causes the rootlet to increase in size. Passing from cell to cell, the fluid becomes changed into sap; but the sap differs in every cell, and each cell, around one well filled, gets out of it a different kind of food. The author contends that it is not possible to get into a plant anything that is a poison to it. The result will be, if poisonous matter is present, that the outer layer of cells will be destroyed, succeeding layers presenting themselves, and also being destroyed, so long as the poison exists around. If the poison gets into the outer cells before they are wholly destroyed, it will not be taken up so readily as nutritious liquid; and in any case, after traversing a few rows of cells, all poison will be retained, while other portions of the plant will remain uninjured.

On the Relation between Pinnate and Palmate Leaves. By MAXWELL T. MASTERS, *F.L.S., Lecturer on Botany, St. George's Hospital, London.*

It is now generally admitted that the different forms of leaves, in spite of their immense number, may be reduced to one or two primary forms, the deviations from which are to be accounted for by such circumstances as increased growth in one direction as contrasted with that in another, arrest of development at particular places, and the like. The ensuing remarks merely tend to confirm this opinion and to add additional illustrations of it.

There are many circumstances leading to the inference that true palmate leaves, as well as those that are palmately divided, are but modifications of true pinnate leaves, or of pinnately divided ones; that in the palmate leaf growth takes place more in a lateral direction than in a vertical one, whereas growth in length at the expense of growth in breadth is the guiding principle in pinnate leaves; the one, so to speak, is a broad leaf, the other a long leaf. Again, in the palmate leaf there is an arrest of development in the portions of the leaf intermediate between the lobes or leaflets according as the leaf is simple or compound, and thus the palmate leaf may be regarded as a contracted pinnate leaf. In support of these assertions the writer may refer to the fact, that pinnate and palmate leaves exist in the same genera; compare the leaves of *Acer pseudo-platanus*, for instance, with those of *Acer Negundo*, the leaves of *Rubus micranthus* with those of *Rubus fruticosus*; indeed the circumstance is of such common occurrence that it is unnecessary to give further illustrations of it. Of greater value for our present purpose are these instances where we have both kinds of leaf on the same plant; take, for instance, *Pyrus trilobata*; trace the transition of the leaves from pinnate to palmate in *Anthyllis vulneraria* or the various species of *Lotus*, wherein the lower leaves are pinnate, the upper palmate. The common raspberry, *Rubus idæus*, will furnish another example; the lower leaves have several pairs of pinnæ, the upper have but three leaflets; in such cases as this (and they are numerous), the two conditions merge one into the other, so that it is difficult, without taking analogy as our guide, to determine whether a ternate or a ternately divided leaf belongs to the pinnate or to the palmate series.

The writer has frequently observed in the oriental plane, *Platanus orientalis*, leaves of almost every variety of shape and marginal incision, from oblong or lance-shaped and entire to palmatisect, the latter being the usual form of the leaves of this tree. In the entire long leaves there is but a single large rib, the lateral ones being much less in size, whereas in the fully developed condition there are three to five main ribs diverging one from the other at an acute angle, a short distance above the base of the leaf (tripli- or quintupli-costate). In the 'Linnæa,' vol. xi. 1829, is mentioned the case of some horse-chestnut leaves which had assumed more or less of a pinnate character; and this season the writer has been fortunate enough to find several presenting similar changes from their ordinary condition, and manifesting almost every intermediate stage between pinnate and palmate leaves; similar instances not unfrequently occur in the leaves of the common white clover, *Trifolium repens*. Were it necessary to do so, many additional instances might be cited leading to the same conclusions, that pinnate and palmate leaves are merely modifications of the same type; that the ternate leaf is an impari-pinnate leaf; the binate leaf is the simplest form of a pari-pinnate leaf; that a palmate leaf is a contracted pinnate leaf, bearing the same relation to the pinnate leaf that opposite leaves do to alternate ones, &c.

On the Migration of the Herring.
By J. M. Mitchell, *F.R.S.S.A., F.A.S., &c.*

In a former paper read at the Economical and Statistical Section last year at Oxford, the author pointed out the great national importance and growing prosperity of the British herring-fishery; in the present paper he restricted himself to that important part of the natural history of the herring connected with its migration, with the view of proving that the herrings visiting the various coasts are undoubtedly natives of the said coasts and the adjacent seas, and that they do not come from any distant part of the ocean. The fact once satisfactorily established, that the herrings belong to the adjacent seas or coasts, may direct public attention more closely to the importance of thoroughly investigating their natural history. The propriety of controverting the statements as to the migration of the herring must be obvious when we find Pennant's account of its progress from the arctic regions continued in each new edition of several works of high authority. Such works state that "the herring comes from the arctic circle, in large shoals of some leagues extent, dividing into lesser shoals on coming towards the north of Scotland, one body proceeding to the west coast of Scotland and to Ireland, and another to the east coast, each directing its course southward." Others state that, although herrings do not come from the arctic circle, they at least come from a considerable distance northward of Scotland. He, however, considered that as the herrings spawn upon our coasts, or in the rivers and bays, they are consequently natives, and that, after spawning, the full-sized herrings proceed to sea in the neighbourhood of the coasts, where they continue, and where they feed until the spawning-season again approaches; while the young on being vivified continue near the spawning-ground until they become of mature size. This is the most natural conclusion; and after several other remarks he said—

1. We find every year, at a certain period of the year, a particular size of herring generally resorting to the same place: for example, the size of the herrings caught off the projecting coast of Stadtland, in Norway, is much larger than the size of those caught on the west coast of Shetland; which kind, again, is nearly twice as large as the first-caught Thurso herrings; and these are smaller than the Isle of Man, Minch, and Loch Fyne herrings, smaller than the Caithness and Banff herrings, and much smaller than the herrings caught off Aberdeenshire, Fifeshire, and Berwickshire. Again, the Yarmouth herrings are smaller than those of Aberdeenshire and Berwickshire; and in the West Highland lochs the size of the herrings is distinctly seen and known; for instance, in some of the Highland lochs for years large quantities have been caught, uniformly of the 10th class, which are of a very superior quality. A size of herrings similar to those of Yarmouth till lately visited Lümfiord in Denmark, and still visits the coasts of that country; while on the Mecklenburg coast, in the Baltic, the size of the herrings is larger than those of Denmark; and proceeding up the Baltic coast above Mecklenburg, namely on the Pomeranian and part of the Prussian coasts, the herrings are fully one-third smaller, and again still further up they are larger, and about the size of the Moray Firth herrings. Thus, those who argue that the herrings come from the north must furnish two kinds of herrings, namely, one kind which in its progress grows smaller on its journey, and another which grows larger. Even in the English Channel the varieties may be easily distinguished in the neighbouring localities; for instance, Professor Valenciennes, in his edition of Cuvier's 'Natural History of Fishes,' vol. xx. p. 47, says, "It is not difficult, with a little practice, to discover the difference which exists between the herrings fished near Calais and those fished near Dieppe; those fished near Calais have the body longer and more flat and compressed on the sides than those of Dieppe, which are rounder and shorter."

2. As to quality, nothing so much proclaims the error of the tale of their all coming from the north as the general state of the herring. For instance, as already mentioned, those caught off Shetland are not nearly so fat as those caught about the same time on the coast from Thurso to Loch Broom. In the first of the season,

those caught in Loch Fyne are not so extremely fat or oily as the early Thurso herrings, and the herrings of Loch Fyne are superior in quality to those of the east coast. Again, there is a marked difference in appearance and quality (and this is easily distinguished by those accustomed to see them) between those caught near Caithness and Morayshire, and those caught off Aberdeenshire and Berwickshire. The quality of the Danish and Baltic herrings is inferior to the Moray Firth and West Highland herrings; and those caught on the coast of Holland are so inferior as not to be pickled at all by the Dutch. The Yarmouth herrings are inferior in some respects to those of the north of Scotland; and the herrings got on the French coasts are also of inferior quality.

3. As to the time of appearance, we find much to prove that the herrings are natives of the seas adjoining the coasts on which they spawn. As a few instances, it may be stated as well known that herrings are caught in Loch Fyne before any are caught near Cape Wrath, and off Berwickshire and Aberdeenshire by the Dutch before any are caught off Caithness; and even off Yarmouth herrings have been caught in May. We find they are not generally caught on the Atlantic side so early as on the east coast of Scotland; and the various times of their approaching the coasts of the Baltic, as already stated, prove the fixity of their places of resort.

4. No well-authenticated instance has been given of the herrings having been seen approaching the south in a high northern latitude. Indeed, although we have conversed with intelligent masters of the Dutch herring-busses, we could not find any one who ever saw any considerable shoal in the northern part of their fishing-grounds; none of the seamen of our Greenland whale-ships ever saw any of those shoals of the magnitude so fabulously described proceeding southwards; and Scoresby, who is of high authority on such a question, made the same statement to ourselves, namely, that he had not, in his many voyages, ever seen any shoals of herrings proceeding southwards.

5. No shoals of herrings have ever been ascertained to exist in the Greenland seas, and no herrings have ever been found in the stomachs of the whales caught there. The food of the *Balæna mysticetus*, or common whale, consists of Actiniæ, Sepiæ, Medusæ, Cancri, and Helices. The *Narwhal* inhabits the seas near Spitzbergen; but only remains of Sepiæ were found in the stomachs of several examined by Scoresby. The *Trichecus rosmarus* (walrus or sea-horse) inhabits the icy seas adjacent to Spitzbergen; in the stomachs of those examined, only shrimps, craw-fish, and young seals were found. Of other marine animals examined by him, Scoresby says the *Alca arctica* (auk or puffin) feeds principally upon shrimps and a small species of *Helix*; of the *Alca alca* (little auk), that it also feeds on shrimps; of the *Colymbus Gylde* (Guillemot), it feeds on shrimps and small fishes; of the *Squalus borealis* (Greenland shark) he says, "A fish resembling a whiting was found in the stomach of one that I killed." Captain Phipps only caught the *Cyclopteris viperus* (sucker) and the *Gadus carbonarius* (coal-fish), and no herrings, when fishing near Spitzbergen. Moreover, Scoresby, in his list of "Fishes found in the Arctic Regions," does not include herrings (Arctic Regions, vol. i. p. 540). Egede, who resided fifteen years in Greenland, after enumeratiug various kinds of fish caught there, says, "No herrings are to be seen" (Natural History of Greenland).

6. We find that those species of whales that feed principally on herrings frequent our own shores and those of Norway. Scoresby says of the *Balæna musculus*, "This species of whale frequents the coasts of Scotland, Ireland, Norway, &c., and is said principally to feed on herrings" (Voyages, vol. i. p. 482); and the *Balæna rostrata* inhabits principally the Norwegian seas.

7. Bloch, the celebrated naturalist (with whom Lacépède in this particular statement coincides), has established that fishes of a similar size, even in fresh water, could not make, from spring till autumn, the long voyage attributed to the herring.

8. The same naturalist further states that "herrings may be found in certain localities all the year through," and this coincides with the opinion of the experienced fishermen at Loch Fyne and other places; and it is well ascertained that herrings, either young or old, may be caught in the Forth any month in the year.

9. The herrings mentioned as coming from the north are never known to return, or even to proceed southward, but when proceeding to some coast for the purpose of spawning.

10. And we may ask why, in some cases, the smallest herrings proceed to the

Baltic, and the larger to the North Sea; and as it is asserted that the whales are the cause of their flying south, why do we not see the whale on every coast every year? Mr. Yarrell, in his valuable work on Fishes (vol. ii. p. 112), truly says, "There can be no doubt that the herring inhabits the deep water all round our coast, and only approaches the shore for the purpose of depositing its spawn within the immediate influence of the two principal agents in vivification—increased temperature and oxygen; and as soon as that essential operation is effected, the shoals that haunt our coast disappear, but individuals are to be found, and many are caught throughout the year."

11. Various other fishes have similar habits in spawning. The salmon ascends the rivers from the sea at particular periods for the purpose of spawning: for this fish no distant seas have, however, been assigned. The sprat appears in shoals in various localities of the coasts of the British Islands from November to March. The shad or *Alosa* is found in shoals in some of our rivers from May to July—in the Severn generally in May, and it continues there about two months; in the Mediterranean, near Smyrna and Rosetta; and it ascends the Nile as high as Cairo in December and January. The pilchard appears in shoals on the coast of Cornwall from June to the end of the year; and the tunny comes in-shore on the coasts of the Mediterranean in summer. All these fishes appear to have the same habit of gregariously visiting various coasts and rivers at particular seasons for a similar purpose; but no one would on this account pronounce them natives or inhabitants of a distant quarter of the globe. In short, from all the circumstances known of the natural history of the herring, in regard to its visits on our own coasts and the coasts of other countries, it is reasonable to conclude that it inhabits the seas in the neighbourhood of the coasts on which it spawns, and that it arrives at particular seasons near the coasts for the purpose of spawning, the shoals leaving the coasts immediately thereafter; and the early or late, and distant or near approach to the coasts in different years perhaps depends, as before remarked, on the clear and warm or dark and cold weather of the season, as well as upon the depth of water at the feeding- and spawning-grounds.

On the Crustacea, Echinodermata, and Zoophytes obtained in Deep-sea Dredging off the Shetland Isles in 1861. *By the* Rev. Alfred Merle Norman, *M.A.*

This paper was supplementary to that of Mr. Jeffreys, and contained an account of the Crustacea, Echinodermata, and Zoophytes obtained during the same dredging-expedition. Mr. Norman mentioned that about 140 species of Crustacea were met with. Eighteen of these, viz. 7 Podophthalmia and 11 Edriophthalmia, were new to Britain. The Podophthalmia consisted of *Portunus pustulatus* (Norman, n. sp.), distinguished by its pustular carapace, by the latero-anterior teeth, which in form resemble those of *longipes*, and by having the swimming-blade of the last pair of feet sculptured with a raised longitudinal and a marginal line; *Pagurus ferrugineus* (Norman, n. sp.); *Crangon serratus* (Norman, n. sp.), allied to *spinosus*, but furnished with seven rows of teeth on the carapace, having an acutely pointed simple rostrum (without the lateral denticular processes which are present in *spinosus*), and a central keel on the fifth segment of the abdomen (instead of diverging lines); *Sabinæa septemcarinata* (Sabine); *Hippolyte polaris* (Sabine); *Hippolyte securifrons* (Norman, n. sp.), nearest akin to the Californian *H. affinis* (Owen), having the rostrum in the form of a broad flat plate armed with eleven teeth above, four or five of which are on the carapace and four below, three pairs of spines on the carapace, the first on each side of the base of the rostrum, the second on the anterior margin just below the eye, the third, very minute, at the junction of the anterior and lateral margins, and three pairs of spines on the telson; *Ctenomysis alata* (Norman), a new genus of Mysidæ allied to *Noctiluca*. *Ctenomysis* has six pairs of thoracic feet, furnished on their inner base with large scales, which serve to protect the external branchiæ situated beneath them; the subabdominal legs are bifurcate and multi-articulate; and the species is easily distinguished by the remarkable form of the antennal scales, which are broad and triangular, and instead of being porrected, are spread at right angles to the body. The front margin of the carapace terminates in five spine-like processes, three frontal, and one on each side below the eyes.

The Edriophthalmia new to Britain which were discovered consist of *Œdiceros parvimanus* (Spence Bate, n. sp.), the genus also new to Britain; *Dexamine tenuicornis* (Rathke); *Liljeborgia Shetlandica* (Spence Bate, n. sp.); *Kröyera altamarina* (Spence Bate, n. sp.); *Calliope Fingalli* (Spence Bate, n. sp.); *Amphithoë albomacula* (Kröyer); *Siphonœcetus typicus* (Kröyer); *Dexamine Vedlomensis* (Spence Bate, n. sp.); *Megamœra* ——; *Heisclados longicauda* (Spence Bate, n. sp.), a new genus differing from *Amphithoë* in having only one branch to the last pair of pleopoda; and *Bopyrus Galatheœ* (Spence Bate, n. sp.).

The author also gave an account of the other rare Crustacea—Podophthalmia, Edriophthalmia, and Entomostraca (including fish-parasites)—which were met with.

Mr. Norman next proceeded to notice the Echinodermata, and stated that forty-seven species were found. The rarer of these were—*Comatula rosacea* (Link) and *Sarsii* (Lovén); *Ophiura* ——, n. sp.; *Ophiocoma Goodsiri* (Forbes) and *filiformis* (Müller); *Ophiopeltis securigera* (Von Düben and Koren); *Asterias* ——, perhaps distinct from *aurantiaca*, having shorter arms, less flattened spines on the under surface, and fewer tubercles on the margin than in the ordinary form; it was dredged in great abundance sixty miles from land in 70–90 fathoms; *Echinus virens* (Von Düb. and Kor.), *Flemingii* (Ball), *neglectus* (Lamarck), and *Norvegicus* (Von Düb. and Kor.), the last very abundant on the Outer Haaf; *Cidaris papillata* (Leske), spines only; *Amphidotus ovatus* (Leske); *Brissus lyrifer* (Forbes); *Cucumaria frondosa* (Gunner) and *fucicola* (Forbes and Goodsir)?; *Psolus phantopus* (L.); *Ocnus brunneus* (Forbes) and *lacteus* (Forbes and Goodsir); *Thyone raphanus* (Von Düb. and Kor.); *Synapta digitata* (Montagu), a vinous purple variety from 70 fathoms; *Phascolosoma radiata* (Alder), and two or three species of *Sipunculus*.

The Zoophytes were next passed in review. The author stated that fifty-nine Polyzoa and fifty-three Hydrozoa and Actinozoa were observed. Among the former were—*Onchopora borealis* (Busk); *Cellularia Peachii* (Busk); *Membranipora Flemingii* (Busk), *Rosselii* (Audouin), and *rhynchota* (Busk), and an undescribed species; *Lepralia concinna* (Busk), *violacea* var. *cruenta*, *punctata* (Hassall), *granifera* (Johnst.), *unicornis* (Flem.) var., and *monodon* (Busk); *Alysidota Alderi* (Busk); *Tubulipora truncata* (Jameson); *Idmonea Atlantica* (Forbes); together with a *Cellepora*, a *Hornera*, and an *Alecto* not yet determined. Of Hydrozoa there were—*Clava multicornis* (Johnst.) and *cornea* (Wright); an undescribed *Hydractinia*, which Mr. Alder has also taken at Cullercoats; an undetermined *Atractylis*; *Coryne implexa* (Alder); *Eudendrium* ——, n. sp.; *Tubularia gracilis* (Harvey), variety; *Sertularia tenella* (Alder), *Gayi* (Lamx.), *gracilis* (Hassall), *alata* (Hincks), *pinaster* (Ell. and Sol.), and *tamarisca* (L.); *Plumularia myriophyllum* (L.) and *frutescens* (Ell. and Sol.); *Laomedea flexuosa* (Hincks) and *Lovéni* (Allman); *Campanularia Johnstoni* (Alder); *Calicella gracillima* (Alder); *Reticularia serpens* (Hassall); and *Grammaria ramosa* (Alder). Among the Actinozoa were—*Tealia digitata* (Müll.), which was abundant on shells of *Fusi* (*antiquus*, *gracilis*, *propinquus*, and *Norvegicus*), and on *Buccinum Dalei* on the Outer Haaf, in from 70–90 fathoms water; *Zoanthus Couchii* (Johnst.), the simple attached and also the free branching state; the splendid *Ulocyathus arcticus* (Sars) in 65 fathoms sand, Outer Haaf; *Caryophyllea Smithii* (Flem.) var. [the *Turbinolia borealis* (Flem.)]; *Pennatula phosphorea* (L.); *Virgularia mirabilis* (L.), and *Sarcodictyon catenata* (Forbes).

With reference to the Sponges, the author remarked that a considerable number had been collected, especial attention having been paid to the small encrusting forms, and that they had been placed in Dr. Bowerbank's hands for examination and description.

On the Cervical and Lumbar Vertebræ of the Mole (Talpa Europæa, *L.*). *By* Professor OWEN, *M.D., LL.D., F.R.S.*

Few of our native quadrupeds have had their osteology more frequently described and studied than the common mole, by reason of the singular and extreme modifications of certain parts of the skeleton, and their readily recognizable adaptation to the peculiar sphere and habits of life of the animal. The author had not anticipated, therefore, in making a recent scrutiny of the skeleton, finding anything worth special notice that had not been noticed before, and could scarcely persuade himself that the fact he was about to communicate had escaped all previous observers. Had it been mentioned, however, in any special monograph on the *Talpa Europæa*, which might have escaped his research, he thought it would have been considered worthy of a reference by the comprehensive and industrious Stannius, and might have led the sharp-sighted De Blainville to a more rigorous scrutiny of the vertebral column than he had bestowed upon it in his Monograph on the Osteology of the Mole—the last on that subject with which comparative anatomy has been enriched. Jacobs, in his generally minute and accurate monograph, when treating of the cervical vertebræ, notices only their spinous processes, and, after describing the large one of the Epistropheus, proceeds,—"Vertebræ colli ceteræ processum spinosum habent nullum, et magis annulis similes sunt, quorum interstitia asperæ arteriæ interstitiis similes sunt" (p. 14), and this description has been geneally repeated. Cuvier writes,—"Dans les Taupes, elles (les cinq autres cervicales) ne forment également que des simples anneaux entre lesquels il y a beaucoup de jeu." So likewise Professor Robert E. Grant writes,—"The remaining cervical vertebræ are behind, like so many loose rings, shorn of their spinous and transverse processes, to allow of the freest motion with safety to the spinal chord." Professor Bell more accurately states, "that in the Talpidæ and the Soricidæ the cervical vertebræ have strong transverse processes, and, excepting the second, do not possess any spinous processes." Professor De Blainville, in a more detailed account of the skeleton, having express reference to the species under consideration (*Talpa Europæa*), says, "Les quatre dernières (vertèbres cervicales) se ressemblent en ce que leur arc, fort étroit, ne présente aucune trace d'apophyse épineuse; les transverses sont également peu marquées, sauf le lobe inférieur de celle de la sixième, assez dilaté, du moins transversalement."

If the cultivators of other, and more particularly of the exact, sciences were to judge of zootomy by the discrepancy of the testimonies adduced by some of the highest names in this science, as to a simple fact, easily determinable by observation, of one of our commonest native quadrupeds, they might conclude that the foundation of our generalizations in comparative anatomy reposed upon an insecure basis, and that the method of obtaining the materials for such basis by the first process of induction—the simple exercise of the eyes—stood in need of much improvement. For while one anatomist implies the absence of transverse processes in the cervical vertebræ of the mole by his silence, and another directly affirms their non-existence, a third describes them as being "strong," and a fourth as being "little marked."

The fact is, that these so-called "transverse processes" are not only present in all the cervical vertebræ, but are variously and peculiarly developed, so as to give the mole the same advantage in strengthening and stiffening its neck, and impeding its lateral inflexions, which the crocodile derives from a similar modification of what might, with equal propriety, be termed in it the "transverse processes of the cervical vertebræ," viz. by their intricate or reciprocally overlapping arrangement, due to the shape and size of the costal elements of such transverse processes. But the mole has so far the advantage over the crocodile in this arrangement as that, whereas the costal part of the transverse process retains its fœtal separation in the cold-blooded Reptilia, it becomes firmly anchylosed to the other parts of the transverse process in the small warm-blooded mammal. In a former memoir, "On the Processes of Vertebræ," Professor Owen had given the results of an analysis of the "cervical transverse process," showing it to consist of the autogenous "pleurapophysis," combined with the exogenous "parapophysis" and "diapophysis." In the mole the pleurapophysis joins the diapophysis, circumscribing the vertebrarterial foramen, and developing a short process from the point of junction. In the third vertebra the pleurapophysis, or costal part of the "transverse process," is compressed and produced backwards and a little outwards and downwards, overlapping the anteriorly produced part of the pleurapophysis of the fourth cervical. This portion of the "transverse process" much resembles the corresponding but separate element in the same vertebra of the crocodile, except that it is "sessile," instead of being supported on a short peduncle; it is, for example, broad, compressed, and produced downwards, forwards, and backwards—its larger and longer posterior portion overlapping the anterior end of the pleurapophysis of the fifth vertebra, as the same part of itself is overlapped by the pleurapophysis of the third vertebra. The posterior part of the pleurapophysis of the fourth cervical of the mole is further interlocked between the pleurapophysis of the fifth cervical below, and the anterior zygapophysis of the same vertebra above. The pleurapophysis of the fifth cervical resembles that of the fourth. In the sixth cervical it is much more developed, both forwards, backwards, and downwards, the pair forming the sides of a deep and wide channel on the under part of that vertebra. In the seventh cervical the pleurapophysis is not developed; the diapophysis forms a small obtuse prominence below the anterior zygapophysis, and, in the ordinary language of anatomy, its "transverse process" would be said to be "imperforate." With regard to the common description of the cervical vertebræ of the mole as mere rings of bone, the term is applicable only to the neural arches of the five last vertebræ, none of which have a spine, except the third and seventh, and in these it appears as a mere tubercular beginning. The bodies of the vertebræ are subdepressed, but otherwise are well-developed quadrate bones, closely united, so as to concur with the peculiar size, shape, and arrangement of the "transverse processes" above described, to give strength to the neck and impede any lateral inflexions. It is easy to show on a recent mole, when the cervical vertebræ are exposed by removal of the enormous masses of muscles with which they are surrounded, that the lateral inflexions of the neck are confined to movements between the *atlas* and *dentata*, the *dentata* and the third vertebra, and between the sixth and seventh vertebræ, but are as effectually impeded in the intervening vertebræ as in the crocodile itself. Nor is the movement upwards and downwards between the same vertebræ of more than a limited extent. The osseous style developed in the *ligamentum nuchæ*, coextensive with the cervical series, and running parallel with the course of their undeveloped spines, stiffens the neck in respect of its vertical inflexions beyond the atlas, as well as augments the lever power of the muscles which raise the head. If the service to the mole of a stiff neck in the fossorial applications of the snout and head had been called to mind, the analogy of the more efficient modification to that end in the burrowing armadillos, might have led to an examination of the actual structure of this part of the skeleton of the mole, which would have rendered unnecessary the present communication on the subject.

One of the objects Professor Owen had in view in troubling the Section with what some might deem too trifling a matter, was to encourage younger comparative anatomists to exercise their skill on indigenous subjects which may any day be brought within their reach. Their organization is far from being exhausted by direct and original scrutiny, and the highest generalizations in comparative anatomy might be tested and illustrated by the anatomy of our commonest fishes, reptiles, birds, and mammals, independently of rarities from foreign shores.

In conclusion, he might further state respecting the mole, that its loins were strengthened by superadditions to their vertebræ, precisely like those discovered by Sir Philip Egerton in the cervical vertebræ of the Ichthyosaurus, viz. by a series of "subvertebral wedge-bones" inserted into the inferior interspace between each of the six lumbar vertebræ, as well as between the first lumbar and last dorsal, and between the last lumbar and the first sacral. These, which Professor Owen had determined to be "autogenous hypapophyses," have their broad, rhomboidal, smooth and slightly convex base downwards, and their narrower end wedged upwards into the lower part of the intervertebral substance. It is obvious that the lumbar region, cooperating with the pelvis, as the fulcrum during the vigorous actions of the hind feet by which the loose earth is kicked out of the burrow, must derive an advantage from this superaddition to their fixation, analogous to that which the Ichthyosaurus derived from the wedge-bones of its cervical vertebræ. The lumbar hypapophyses of the mole had not escaped the notice of the sharp-sighted Jacobs, who speaks of them as "ossicula sesamoidea" (*loc. cit.* p. 17); but he deduces no physiological consequence from the fact; and his passing notice of the structure had not been recognized by any subsequent writer on the osteology of the Insectivora. From no systematic work or monograph on comparative anatomy, indeed, could the student acquire any hint of so curious a fact that the vertebral column of the mole combined two peculiarities which are separately given in the reptilian class, viz. to the Crocodilia and the Enaliosauria respectively. This paper was illustrated by diagrams of the structures described.

On some Objects of Natural History from the Collection of M. Du Chaillu. *By* Professor Owen, *M.D., LL.D., F.R.S.*

The author's first knowledge of this zoological collection was derived from a letter sent by M. Du Chaillu, dated Gaboon, June 13, 1859, and received in the British Museum in August 1859, in which M. Du Chaillu specified the skins and skeletons of the gorilla or n'gena, kooloo-kamba, nschiego, and nschiego-mbovie which he had collected, offering them for sale, with other varieties, to the British Museum. Professor Owen replied, recommending the transmission of the collection to London for inspection, with which recommendation M. Du Chaillu complied, bringing with him, in 1861, all the varieties he had named, with other objects of natural history, from which he permitted selections to be made. The skins of the adult male and female of the young of the *Troglodytes gorilla* afforded ample evidence of the true coloration of the species. In the male, the rufo-griseous hair extends over the scalp and nape, terminating in a point upon the back. The prevalent grey colour, produced by alternate fuscous and light-grey tracts of each hair, extends over the back, the hair becoming longer upon the nates and upon the thighs. The dark fuscous colour gradually prevails as the hair extends down the leg to the ankle. The long hair of the arm and forearm presents the dark fuscous colour; the same tint extends from below the axilla downwards and forwards upon the abdomen, where the darker tint contrasts with the lighter grey upon the back. The scanty hair of the cheeks and chin is dark; the pigment of the naked skin of the face is black. The breast is almost naked; and the hair is worn short or partially rubbed off across the back, over the upper border of the iliac bones, in consequence, as it appears, of the habit ascribed by M. Du Chaillu to the great male gorilla of sleeping at the foot of a tree, resting its back against the trunk. Professor Owen proceeded to describe the colour of the female gorilla, which, it appears, was generally darker and of a more rufous tint than the male. In one female the rufous colour so prevailed as to induce M. Du Chaillu to note it as a 'red-rumped variety.' In the young male gorilla, 2 ft. 6 in. in height, 1 ft. 7 in. in the length of the head and trunk, and 11 inches across the shoulder, the calvarium is covered with a well-defined "skull-cap" of reddish-coloured hair. The back part of the head, behind the ears, the temples, and chin are clothed with that mixture of fuscous brown and grey hair which covers with a varying depth of tint the trunk, arms, and thighs. The naked part of the skin of the face appears to have been black, or of a very dark leaden-colour; a few scattered straight hairs, mostly black, represent the eyebrows. A narrow moustache borders the upper lip; the whole of the lower lip and sides of the head are covered with hair of the prevailing grey fuscous colour. The rich series of skulls and skeletons brought home by M. Du Chaillu illustrate some important phases of dentition. These phases were specified by Professor Owen at length. The deciduous or milk dentition, it was remarked, was, in the youngest specimen of the gorilla, something similar to that of the human child, but an interspace equal to half the breadth of the outer incisor divides that tooth from the canine, and the crown of the canine descends nearly two lines below that of the contiguous milk molar. The deciduous molars differed from those of the human child in the more pointed shape of the first, and much larger size of the second. The dentition of the young gorilla corresponds best with that exemplified in the human child between the eighth and tenth years; the difference, however, is shown in the complete placing of the true molar, whilst the premolar series is incomplete. It was worthy of remark, also, that in both specimens examined the premolars of the upper jaw had preceded those of the lower jaw, and that the hind premolar had come into place before the front one. In the later development of the canines and the earlier development of the second molars of the second dentition the gorilla differs, like the chimpanzee and the orangs, from the human order of dental development and succession. An opportunity of observing this order in the lower races of mankind is rare. Professor Owen availed himself of the opportunity in the case of the male and female so-called dwarf Earthmen from South Africa, exhibited in London in 1855. He found their dentition respectively at the phase indicative of the age of from seven to nine in the English child; other indications agreed with this evidence of immaturity. The children were of the dwarf Boschisman race, and were dressed and exhibited as adults.

Both showed the same precedency in development of canines and premolars which obtains in the higher races of man. Referring next to the variety of the chimpanzee brought by M. Du Chaillu from the Camma Country and from near Cape Lopez, Professor Owen remarked that this species accords specifically in its osteological and hirsute development with the *Troglodytes niger*. It is stated by M. Du Chaillu to be distinguished by the natives of Camma as the nschiego-mbovie, from the common chimpanzee (*Troglodytes niger*), called by them the nschiego. From the character of the skins of the male and female specimens of this species brought by M. Du Chaillu to London, Professor Owen would have deduced evidence of a distinct and well-defined variety of *Troglodytes*.

Statistics of the Herring Fishing. Communicated by C. W. Peach.

[Compiled by Mr. Peter Reid, and published in his paper the "John o'Groat Journal."]

Quantity Branded in Wick District during the past Six Years, to 30th September in each year.

Year.	Barrels.	Year.	Barrels.
1855	79,713	1858	54,348
1856	60,017	1859	50,256
1857	48,612	1860	60,559

Number of Boats, Yearly Average, and Total Quantity caught annually at Wick since 1836.

Year.	Boats.	Average.	Total.
1837	600	100	60,000
1838	550	135	74,250
1839	620	110	68,200
1840	720	91	65,520
1841	750	126	94,500
1842	800	125	100,000
1843	820	107	87,740
1844	900	100	90,000
1845	960	96	92,160
1846	900	103	92,700
1847	765	110	84,150
1848	813	114	92,682
1849	800	140	112,000
1850	804	100	80,400
1851	1000	100	100,000
1852	1000	75	75,000
1853	960	120	115,200
1854	920	104	95,680
1855	952	141	134,232
1856	1050	86	90,300
1857	1100	73	80,300
1858	1061	80	84,880
1859	1094	79	86,426
1860	1080	92	99,254
1861	1100	87	95,700

Number of Boats Fishing at each Station during the past Five Years.

District.	1856.	1857.	1858.	1858.	1860.
Wick	1050	1100	1061	1094	1080
Lybster	292	265	259	228	200
Forse	36	35	36	35	36
Latheronwheel	22	28	28	30	28
Dunbeath	80	83	96	97	95
Helmsdale	185	210	240	218	185
Brora	35	28	21	30	21
Cromarty	148	170	154	150	156
Findhorn	15	18	24	24	19

District.	1856.	1857.	1858.	1859.	1860
Burghead	65	68	66	46	60
Hopeman	38	45	52	41	51
Lossiemouth	107	90	106	104	116
Buckie district	201	250	264	208	214
Whitehills	24	22	30	28	27
Banff	21	19	22	13	18
Macduff	67	62	64	58	58
Gardenstown	44	48	54	54	48
Fraserburgh	243	331	334	378	328
Peterhead	239	245	268	271	294
Anstruther	290	300	300	400	360
Dunbar	220	183	174	190	150
Eyemouth	140	120	130	154	158
North Sunderland	74	78	86	70	78
Orkney	360	380	370	330	347
Lewis (early fishing)	260	300	420	460	475

Average in each District from Orkney to Northumberland for the past Five Years.

Wick	86	73	80	79	92
Lybster	91	75	62½	43½	94
Forse	100	60	61	35½	88
Latheronwheel	84	70	70	23	84
Dunbeath	84	67	68	18	80
Helmsdale	80	91	57	40	95½
Brora	65	78	69	41	120
Cromarty	45	46	20	47½	81
Findhorn	40	59½	24	50	54
Burghead	80	85	56	106	100
Hopeman	110	85	92	120½	150
Lossiemouth	100	72¾	103	90	112
Buckie	130	82½	72½	70	106
Whitehills	95½	125	22	31	49¼
Banff	83	80⅓	25	35	43¼
Macduff	137	103	38½	46	63½
Gardenstown	163	142	108	68	100¾
Fraserburgh	128	86¾	143½	71	68½
Peterhead	146¼	79	96	56½	74
Anstruther	64	80	235	70	230½
Dunbar	—	61½	176	58	160½
Eyemouth	—	127	115	103	107
North Sunderland	134	76⅓	50	109	84½
Orkney	40	30½	36	35	34
Lewis (early fishing)	50	45	17	39½	77

Total Catch at each Station from Orkney to Northumberland for the past Four Years.

District.	1857.	1858.	1859.	1860.
Wick	80,300	84,880	86,426	99,254
Lybster	24,525	16,187	9,918	18,800
Forse	2,100	2,196	1,242	3,168
Latheronwheel	1,960	1,960	690	2,352
Dunbeath	5,561	6,528	1,746	7,600
Helmsdale	19,110	13,680	8,720	17,667
Brora	2,184	1,449	1,230	2,520
Cromarty	7,820	3,080	7,191	12,636
Findhorn	1,071	576	1,200	1,026
Burghead	5,780	3,696	4,876	6,000
Hopeman	3,825	4,784	4,940	7,650
Lossiemouth	6,547	10,918	9,360	12,992

District.	1857.	1858.	1859.	1860.
Buckie district	20,625	19,140	14,560	22,676
Whitehills	2,750	660	868	1,332
Banff	1,529	550	455	778
Macduff	6,386	2,464	2,668	3,687
Gardenstown	6,816	5,832	3,672	4,836
Fraserburgh	28,714	47,929	26,838	22,475
Peterhead	19,355	25,728	15,311	21,850
Anstruther	24,000	70,544	28,000	83,000
Dunbar	11,254	30,624	11,020	23,304
Eyemouth	15,240	14,950	15,862	16,906
North Sunderland	5,709	4,300	7,630	6,591
Orkney	11,590	13,320	11,550	11,798
Lewis (early fishing)	13,500	7,140	18,170	28,875

Total Catch of Herrings for the past Eight Years, from Northumberland to the Lewis, excluding Zetland and the Ayrshire and Argyleshire Coasts.

Year.	Barrels.	Year.	Barrels.
1854	348,881	1858	393,035
1855	461,549	1859	294,143
1856	337,443	1860	439,879
1857	329,251	1861	467,966.

Remarks on the late Increase of our Knowledge of the Struthious Birds. By P. L. Sclater, *M.A., Ph.D., F.R.S.*

After pointing out the general characters of the birds of the order *Struthiones,* and the peculiarities displayed in the structure of the two families, the *Struthionidæ* and *Apterygidæ,* of which alone recent representatives were known, Dr. Sclater called the attention of the Meeting to the large increase in our knowledge of the species of this group of birds which had recently taken place. Until lately, each of the types, *Struthio, Rhea, Casuarius, Dromæus,* and *Apteryx,* had been supposed to be represented by a single species. There now appeared to be indications, more or less precise, of the existence of twelve species of *Struthionidæ,* and (as the author has already shown in his joint Report with Dr. Hochstetter on the genus *Apteryx**) four species of the family *Apterygidæ.*

The following Table was exhibited, giving the names of these species and their localities, as far as they were known.

TABULA AVIUM STRUTHIONUM.

Fam. I. Struthionidæ.

a. Struthioninæ.

α. Struthio.

1. camelus, ex Afr. et As. Occ.

β. Rhea.

2. americana, ex rep. Argent.
3. macrorhyncha, ex rep. Argent. (?).
4. darwini, ex Patagonia.

b. Casuariinæ.

γ. Casuarius.

5. galeatus, ex ins. Ceram.
6. bicarunculatus, ex patr. ign.
7. kaupi, ex ins. Salawatty.
8. uni-appendiculatus, ex patr. ign.
9. bennettii, ex Nov. Britann.
10. australis, ex Nov. Holl. Bor.

δ. Dromæus.

11. novæ hollandiæ, ex Austr. Or.
12. irroratus, ex Austr. Occ.

* See *anteà,* p. 176.

Fam. II. Apterygidæ.

Apteryx.

1. australis, ex Nov. Zeland. ins. bor.
2. mantelli, ex Nov. Zeland. ins. media.
3. owenii, ex Nov. Zeland. ins. med.
4. maxima, ex Nov. Zeland. ins. med.

Dr. Sclater illustrated his remarks by exhibiting a series of drawings taken from examples in the Gardens of the Zoological Society of London, which, he stated, contained living specimens of no less than ten out of these sixteen species.

On a New Mining Larva, recently discovered. *By* H. T. Stainton, *F.L.S.*

The author remarked that it had long been notorious that larvæ of several orders of insects lived between the two surfaces of leaves of plants, forming tracks in the fleshy substance of the leaf, and hence termed leaf-miners; that from the time of Reaumur, nearly 130 years ago, observers had often paid considerable attention to this class of insects, and that latterly a continued attempt had been made, both here and in Germany, to discover all the species of leaf-mining larvæ which belonged to the order Lepidoptera.

Amongst the leaf-mining larvæ were representatives of the four orders, Coleoptera, Hymenoptera, Lepidoptera, and Diptera; but at present few entomologists attempt to study more than one order, and hence a collector of Coleoptera would naturally neglect all Lepidopterous larvæ and those he suspected to be Lepidopterous; in like manner a collector of Lepidoptera would reject all Coleopterous larvæ and those he suspected to belong to that order. Hence the same larva might be suspected by both parties and neglected accordingly. A larva which had lately attracted considerable attention had in this way been noticed long ago, both here and abroad, by Lepidopterists, but, being reputed by them a Coleopterous larva, had been neglected accordingly.

Herr Kaltenbach of Aix-la-Chapelle, who had been devoting his attention to mining-larvæ of all orders, had met with this larva, and reared from it a *Micropteryx*; and last spring Dr. Hofmann, of Ratisbon, had also reared a larva of the same genus.

The genus *Micropteryx* is a genus of small moths of the group *Tineina*; but the structure of the palpi is so singular, the neuration of the wings so peculiar, and the wings so slightly clothed with scales, that some authors were disposed to question their right to be considered Lepidoptera. Westwood, in 1840, had expressed his regret that the transformations of so anomalous a genus had not been detected.

The larvæ of *Micropteryx* had now been found very plentifully, and had clearly established that the genus was truly *Lepidopterous*, as the only group of insects to which they could otherwise have been referred, the *Trichoptera*, have larvæ of a very different structure.

The most striking peculiarity of these *Micropteryx*-larvæ is a slight lateral protuberance on the fifth segment, which has been noticed in several species. These larvæ are totally devoid of legs, and the hinder segments are much attenuated.

On Varieties of Blechnum Spicant *collected in* 1860 *and* 1861. *By* A. Stansfield.

The *Blechnum Spicant* of Linnæus, *Lomaria Spicant* of Hooker, is one of the commonest of all known ferns. Its range of elevation extends from the sea-level to the summits of the highest mountains, though it flourishes most in the subalpine regions. It is found in greater or less abundance in most of the geological formations, most frequently of all in the siliceous formations of the Silurian, Old Red Sandstone, and the Coal-measures, and is least plentiful on the mountain limestone and the chalk. From its extensive diffusion we might be led to expect that varieties would be numerous, but till within a very late period these seem not to have been recognized by the British botanists.

Bentham, in his recent work on British plants, says it is one of the *most constant* of all known ferns. Sir W. J. Hooker, in his 'Species Filicum,' notices but one variety, found near Warrington, Lancashire, by Mr. Hobson of Manchester, about forty years ago. It is to Mr. Moore, of the Botanic Garden, Chelsea, in the "Nature-printed Ferns," that we are indebted for the bringing of the varieties of this fern most prominently before the British pteridologist.

During the last three years I and a few friends have examined some millions of plants of the *Blechnum Spicant* in various parts of the United Kingdom, collecting all the abnormal forms we could meet with, afterwards carefully growing them, watching sedulously their development, and noting their peculiarities. This, speaking for myself, whilst it has afforded me a fund of innocent enjoyment, has enabled me to report on the permanency of some forms and the fugacity of others, and on the general characters of the whole. I purpose here noticing only the more striking among the permanent forms that have stood the test of cultivation, some of them for two and others for three years.

These have perfectly distinct and fixed characters, like species; and in those that have been raised from spores, the complete identity of the parents has been maintained. For instance, out of ninety plants raised from the spores of *Blechnum Spicant subserratum*, no difference from the parent plant could be detected, whilst the minutest peculiarities were faithfully repeated. Thus a few of the lobes, both of the fertile and barren fronds of the parent plants, were twins, or bilobate: the young plants have all the same peculiarity. Out of seventy plants raised from spores of *Blechnum S. imbricatum*, every plant seemed perfectly identical with the parent. Out of 100 plants raised from spores of *Blechnum S. ramosum*, all had the same ramosely cristate termination of the parent.

Our ideas of *species* are exceedingly vague and indefinite, and indeed it may be questioned whether they have any real foundation in nature. Doubtless great numbers of plants now regarded as species are merely variations of other forms. Be this as it may, we know that the forms of *Blechnum Spicant*, to which I am about to refer, are variations from a primary type, though they possess specific differences which in other genera would, I apprehend, be sufficient to constitute them *species*. But in whatever light we regard them, it is quite essential that we should give distinct names to obviously distinct and permanent forms.

The form of *Blechnum Spicant* which first arrested my attention was the *B. S. concinnum* of Moore. It was so essentially distinct from the common type, and so beautiful an object, that it determined me at once to give the *Blechna* a thorough investigation. It was gathered in the valley of the Conway in North Wales early in 1859. I subsequently gathered it near the foot of Twelve Pins, Connemara, Ireland, and in Thieveley Scouts, near Burnley, Lancashire. Fronds linear, from 6 to 12 inches in length, and from $\frac{1}{4}$ to $\frac{1}{2}$ inch in breadth; lobes very short, subrotund, and beautifully crenated on the margins. Fertile frond: lobes little more than nodes bearing sori. In cultivation the linear outline of the frond is maintained, but when liberally supplied with water the lobes become enlarged, so as to make a slight approach to *B. S. strictum*, from which, however, it remains quite distinct.

Blechnum Spicant strictum (Moore). Fronds ovate-lanceolate, from 6 to 12 inches in length, and from $\frac{1}{2}$ to 1 inch in breadth; lobes mostly recurved, and distinctly serrated on the margins. Fertile frond longer than the barren, lobes short and serrated on the margin. I have gathered this beautiful form in the valley of the Conway, and near the Pass of Nant Francon in Wales, in Connemara, Ireland, Vale of Todmorden, Lancashire, and some other localities. It is perfectly constant under cultivation, and a most interesting object.

Blechnum S. lancifolium (Moore). Somewhat less than the normal type; fronds acutely lanciform, entire from the apex to $\frac{1}{3}$rd their length; fertile fronds still more acutely lanciform, lobes much abbreviated above and below. This has been gathered near Todmorden, Lancashire, Trefriw, North Wales, and in Connemara.

Blechnum S. subserratum (Moore). Size of the normal type; fronds rather narrower; lobes ascending, serrated on the inferior, and frequently auricled on the superior margin; fertile fronds longer than the barren, lobes deeply serrated on the inferior limb, frequently all but bipinnatifid. Gathered near Todmorden, and near Castle Howard, Yorkshire.

Blechnum S. imbricatum (Moore). Fronds from 4 to 6 inches long, and from 1 to 2 inches broad, nearly ovate in outline, thick and leathery in texture; lobes closely imbricated, recurved, the apical lobe twisted; fertile fronds very little longer than the barren. Gathered in the Vale of Todmorden, in Rossendale, Lanc.;

near Barnstaple, Devon, and some other places. It is quite constant under cultivation; of seventy plants raised from spores, all inherited the characteristics of the parent.

Blechnum S. imbricato-subcrenatum. Fronds ovate-lanceolate in outline, 6 to 9 inches long, from 1 to 2 inches broad; lobes closely imbricated and recurved, subcrenate on the lower limb. Gathered in Connemara, Ireland, in 1860.

Blechnum S. anomalum (Moore). Fronds from 6 inches to a foot in length, and 1 inch or a little more in breadth; lobes very narrow, distant, attenuated; all the fronds fertile halfway down, barren below. This is certainly a very striking anomaly, and one that could not have been anticipated by those best acquainted with the normal type. I at first attributed the change to the situation of its growth, the ground on which it was first found growing being very wet; but I have since found it on dry hedge-banks and near dry walls, where the condition before mentioned was altogether absent. Whatever may have been the cause, the change is very wonderful, and two plants can scarcely be more unlike than the *Blechnum S. imbricatum* and the *B. S. anomalum.* About three-fourths of the plants hitherto gathered have been constant. It has been found near Todmorden, in Connemara, Ireland, in North Wales, and some other places.

Blechnum S. projectum (Moore). This is a most heterodox variety, not at all conforming to any law of regular development. Fronds from 4 to 10 inches long, some of them almost entire, being little more than a winged rachis, others with here and there a projecting lobe beyond the rachidal membrane, and others again with large projections in lieu of lobes starting from the middle of the frond, others, still, bearing projections or branches near the terminations in the most irregular manner. Fertile fronds much longer than the barren, little more than a branched rachis bearing sori without the intervention of the usual side lobes. This bears very little resemblance to the typical form, and is altogether a most singular and grotesque plant. It was gathered near the foot of Ben Lawers, Scotland, and, as described above, is permanently irregular in its development.

Blechnum S. variabile. Fronds the length of the normal type, variously furcate, and ramose terminally; lobes below very much depauperated for more than half the length of the frond. Gathered in the Clova Mountains, Scotland.

Blechnum S. caudatum (Moore). Fronds 4 or 6 inches long, and 1 to 1½ inch broad, contracted below, and terminating in a cauda more than one-third the length of the frond. Gathered in North Wales.

Blechnum S. diversifrons (Moore). Fronds less than the common type, very much abbreviated below; lobes suddenly starting to the full length in the middle of the fronds, distant. Some of the fronds perfectly linear, being little more than ¼ inch in breadth, whilst others, again, have projecting lobes variously distributed; fertile frond being little more than a winged rachis bearing the sori. Found in the Vale of Todmorden.

Blechnum S. latifrons (Moore). Fronds 6 to 9 inches long, and 2 to 3 inches broad, distinctly caudate at the end, very coriaceous in texture. Gathered in two or three places within the Vale of Todmorden.

Blechnum S. brevilobum (Moore). Fronds from 3 to 6 inches long, and from ¼ to ½ inch broad; lobes rather distant, very short, like blunt triangular teeth on each side the rachis. Found in the Vale of Rossendale.

Blechnum S. ramosum (Moore). Fronds from 6 to 9 inches long, and from ½ to 1 inch broad, every frond terminating in large crests or ramose cristations, these crests again producing other crests. Gathered near Todmorden, also in Connemara, Ireland.

Blechnum S. heterophyllum (Moore). Fronds exceedingly varied, some nearly normal, others depauperated throughout, others, again, having lobes projecting beyond the margin intermixed with abbreviated and normal ones. Gathered in the Vale of Todmorden.

Blechnum S. erosum. Less than the normal type; fronds very narrow; lobes scarcely developed at all, very much eroded. Gathered near Todmorden.

Blechnum S. polydactylum (Moore). Less than the normal type, all the fronds ending in fingered terminations. Gathered in Connemara, and also near Todmorden.

Blechnum S. crispum (Moore). Rather less than the species; lobes very much crisped and twisted; fronds sometimes terminating in crispy furcations. Gathered in North Wales.

Blechnum S. trinervium (Moore). Nearly the size of the species, characterized by the lowest pair of lobes being developed into miniature fronds. Found in Ireland.

Blechnum S. multifurcatum (Moore). Distinguished by the fronds, both barren and fertile, being variously branched and furcate at the ends. Gathered near Todmorden, in Rossendale, and other places.

The forms previously mentioned are all distinct from one another, and are beautiful and interesting objects, either for pot culture or fern houses, for Wardian cases or rockwork in the hardy fernery.

The following varieties (many of them gathered during the past season) I have submitted to Mr. Moore, who considers them quite distinct and permanent forms, and has named them accordingly. Most of them are exceedingly interesting, but my acquaintance with them is not sufficiently extended to enable me to vouch for their permanency.

Blechnum S. serratum.
—— repandum.
—— mundulum.
—— apiculatum.
—— aberrans.
—— porrectum.
—— pauperculum.
—— imparatum.
—— minimum.

Blechnum S. variegatum.
—— cristatum.
—— deficiens.
—— furcatum.
—— subcrenatum.
—— tridactylum.
—— præmorsum.
—— dentigerum.
—— abruptum.

Observations on the Development of Synapta inhærens. *By* Professor WYVILLE THOMSON, *LL.D.*

On some Points of Interest in the Structure and Habits of Spiders. By TUFFEN WEST, *F.L.S.*

The object of this paper was stated to be, rather to dissipate erroneous opinions commonly held, by the mention of facts, than to set forth novelties; and by adverting to some of the many points of interest in the structure and habits of spiders, to lead to their being regarded with better feelings, and perhaps more attended to by students of Natural History. A more favourable opportunity could not present itself than such an occasion, when those who professedly study science are met and listened to by the intellectual and the highly cultivated, with whom rests the privilege of giving to the age its prevailing tone of thought. The colouring of spiders is seldom other than rich in its tones; in making figures of them great difficulty is experienced in getting colours of sufficient brightness. That there is an adaptation of the general tone of colouring to the places inhabited by different spiders is certain; how far individuals that have arrived at maturity may be able on changing their abode to modify their colours is not known, though it is probable, from the great variety readily observable in this respect, that during growth at any rate there may be some such adaptive power. The alterations in colour of the anterior pair of eyes in some spiders, from ruby-red or emerald-green to golden-yellow, by a perceptible internal motion, are very remarkable, and the means by which such change is effected deserve careful study. In the instincts of spiders there is much to interest. The intimate structure of the web of the Diadem-spiders is known to most as a favourite microscopic object; the radii in this web are cords serving principally for the support of the highly elastic spiral line, with its drops of viscid material. In the Ciniflonidæ none of the lines forming the snare are viscid, but insects are quite as effectually entangled by a pair of fine double lines, so disposed along a framework as to form very numerous double loops. The apparatus employed in the construction of these loops is composed of a double row of spines on the metatarsus of each hind-leg. Some of the tent-forming spiders in fine weather make their covering of a very slight texture, but in wet gusty weather this is strengthened by additional layers of silk, to which are added legs, wings, &c., the refuse of their prey. Many spiders manifest proofs of great affection for their offspring: the female *Lycosæ* carry their cocoons constantly about with them, attached to their spinners; and when the young are hatched, they affix themselves to the hairs on the legs, abdomen, &c. of their parent. *Pholcus phalangioides* carries its cocoon in its mouth: *Dolomedes mirabilis* also, attaching a few lines from the spinners as well; it is only left to take food. The young of many species of *Theridion* live with their parent for some time in a tent constructed by her, and are, till able to shift for themselves, supplied by her with food.

The structure of many spiders presents numerous points of interest. In *Atypus Sulzeri,* our only British representative of the great Bird-catching Spiders of the tropics, the jaws are so enormously developed as to render necessary an unusual elevation of the front of the cephalothorax, at the highest part of which, on a short column, the eyes are seated. This spider constructs a long tube of silk in a burrow formed in sloping banks, like its relative the "Trap-door spider;" the entrance, however, is protected in a different way—the end of the tube, hanging out in a collapsed state, lies concealed amongst grass, &c. Several remarkable varieties in the form of the cephalothorax in species belonging to the genera *Walckenaëra, Neriene,* &c., were mentioned, details respecting which will be found at length in the second part of Mr. Blackwall's work on our native species, shortly to appear under the auspices of the Ray Society. The extraordinary difference in size between the males and females of many spiders was alluded to: in some, as the Diadem-spider of our gardens, the female is three or four times as large as the male, and powerful in proportion; wayward and capricious, she is apt to seek to enjoy by making a meal of him, hence the disproportionate length of the limbs. Some spiders, however, especially amongst the smaller species, are gregarious and social.

Many other interesting circumstances respecting spiders might have been mentioned but for the fear of taking up too much time; as the habits of *Argyroneta aquatica,* which, though an air-breathing spider, lives habitually in water, carrying an extempore diving-bell about with it, and forming a habitation by imprisoning air at the bottom of the water by fine silken lines. The power of restoring amputated limbs, of sustaining entire abstinence from food for very lengthened periods, the probable duration of life, the graceful form of the cocoons, were pointed out as well worthy of attention.

Some interesting facts respecting the spiders found in coal-mines were then alluded to. Some months ago it was publicly stated that spiders' webs occurred in the abandoned workings of the Pelton Colliery, near Chester-le-Street, county of Durham; specimens of the architects of these webs, on being submitted to careful examination, proved to be *Neriene errans,* a small spider met with occasionally about the time of the hay-harvest. It appears probable that some individuals were carried down into the pit with the provender for the horses, of which about seventy are constantly employed in the workings. There they have bred freely. Mr. West found their cocoons in great quantity on the roof of the working, and obtained some little insight into the nature of their food by finding entangled in a portion of web, a specimen of the brown plume-moth, one of the midges, and a number of serrate hairs from a hairy caterpillar. The special point of interest, however, is that with altered circumstances a modification appears to have taken place in the instincts of these spiders. In their natural state they are only known as solitary wanderers, making no web of any kind, further than a few scattered lines. Have their instincts so changed by scantiness of and difficulty in securing prey that in the coal-mine they become gregarious, and live in large colonies? from being neither spinners nor weavers, they take to constructing sheets of web of comparatively vast size. Mr. West saw one 30 feet long by 4 feet 6 wide, hanging from about the middle of the roof; and Mr. David P. Morrison, who lives at Pelton, and was the first to carefully observe them, has recorded the occurrence of many nearly as large. Is any alteration in the *structure* of the spiders taking place? Are the optic nerves becoming atrophied, the number of the spinnerets increasing, and the glands secreting the silk increasing in size? Here is a fine opportunity afforded for practically testing Mr. Darwin's theory of the origin of species, since we know, from the time the pit has been worked, that it cannot be long since the first individuals were taken underground. Will the naturalists who may follow us have the opportunity of observing the formation of a blind variety, differing in so many respects from its original, that, had it not been certainly known whence it sprung, it would have ranked without hesitation as a distinct species, analogous to the Cave Crustaceans, &c.? The fact that all the examples brought from the pit die very shortly after their removal thence, may have a close connexion with the altered barometric pressure, and is not without interest.

Physiology.

On the Structure and Growth of the Elementary Parts (Cells) of Living Beings. By Professor Lionel S. Beale, *M.B., F.R.S.*

The object of the author was to prove, amongst other points, that all tissues consist of elementary parts, and that each elementary part (cell) is composed of matter in two states—germinal matter *within*, and formed material *externally*. The only part of the matter of which living structures are composed which possesses the power of selecting pabulum, and of transforming this into various substances—of growing, multiplying, and forming tissue—is that which he terms *germinal matter*. The powers of growth of this matter are infinite; but for the manifestation of the powers, even in a limited degree, certain conditions must be present. Growth always occurs under certain restrictions. Germinal matter is composed of spherical particles, and each of these of smaller spherules. New centres of growth originate *in* the spherical masses. Nuclei therefore are not formed first, and other structures built up around them; but nuclei are new centres, originating in pre-existing centres. All tissue (cell-wall, intercellular substance, &c.) was once in the state of germinal matter, and resulted from changes occurring in the oldest particles of the masses of germinal matter. What is termed the "intercellular substance" corresponds with the cell-wall of a single cell; and there is no more reason for believing that this structure results from any inherent power to form matrix, or that the intercellular substance is simply deposited from the nutrient fluid, than for believing that the capsule of mildew can grow independently of the matter it encloses, or be formed by being precipitated from the medium which surrounds it. There is a period in the existence of cartilage and allied structures in which there is no true "intercellular substance." In nutrition, the inanimate matter permeates the formed material, and passes into the germinal matter, where it undergoes conversion into this substance. The old particles of germinal matter become converted into formed material. Growth, therefore, always takes place from centre to circumference. The relative proportion of germinal matter and formed material varies greatly in different elementary parts, in the same elementary part at different periods of its growth, and in the same tissue under different circumstances. The more rapidly growth proceeds, the larger the amount of germinal matter produced in proportion to the formed material. In all living beings, the matter upon which existence depends is the germinal matter; and in all living structures the germinal matter possesses the same general characters, although its powers and the results of its life are so very different.

On a Method of Craniometry, with Observations on the Varieties of Form of the Human Skull. By John Cleland, *M.D.*

The author remarked that, notwithstanding the great interest which attached to the changes of form which the human skull undergoes in the passage from infancy to old age, and the varieties of its appearance in different nations, little had been done as yet to determine what the various superficial appearances indicated as to the exact form of the skull. It was as if artistic views had been taken of the brain's habitation from various points, but as yet no ground-plan attempted. And this apparently resulted from the skull being studied rather as an object of physiognomical interest than as an anatomical structure. He then pointed out the method which he had invented for making accurate measurements of the relations of any series of points on the circumference of the cranium. The instrument consisted of a framework and bars, by which the vertical and horizontal distance of any spot from a fixed point could be determined. By means of a short series of figures it was thus possible to convey to persons at a distance materials for making perfectly accurate measurements of skulls which they had not even seen a drawing of. The reader of the paper then went on to show that, although there was great difference between savage and cultivated nations in the relative breadth of the cranium and of the face, yet that, as regarded the proportions in the mesial plane of the front, middle, and back parts of the head, there was no characteristic difference of size or shape even between the European and the African. The peculiar appearance of the skulls of Negroes, Australians, Caribs, &c., compared with civilized nations, depended on the way in which the teeth were set, on the development of the frontal ridge to the extent of giving the appearance of a retreating forehead, and on the manner in which the whole head was balanced on the vertebral column, but not on diminished size of the anterior lobes of the brain. Dr. Cleland pointed out that one of the most characteristic differences between man and all other mammals consisted in the fact that the human head was balanced in the erect posture, and only required muscular action to steady it; while in the chimpanzee and all lower mammals the head was constantly suspended by the action of muscles and elastic structure. To preserve the balance of the human head, it was necessary that a change in the joint which articulated it to the neck should accompany the growth of the individual in such a manner as to tilt the skull further and further backwards on the vertebral column from infancy to adult age, that the back of the head might be balanced against the increasing weight of the forehead and face; and he demonstrated that such a change really took place. Hence also the feminine head, there being a smaller development of the face-bones, had a characteristic position in relation to the neck, distinguishing it from the masculinely developed head. He showed that in the discussions which had lately taken place to such an extent among anatomists as to the degree in which the cerebellum was covered by the brain proper, in man and in monkeys, everything depended upon the level on which the skulls were placed, for that in all mammals the anatomically superior aspect of the cerebellum was separated from the cerebrum by the tentorium only, and the real difference lay, not in any disproportionate addition to the posterior part of the human cerebrum, but in this, that the human skull, together with the contained cerebrum, was much more curved upon itself in man than in any other animal. Thus, if the back of a sheep's skull were placed in the same position as the back of a human skull situated as in the erect posture, the nose of the former would be directed upwards.

On the Action of Lime on Animal and Vegetable Substances.
By JOHN DAVY, *M.D., F.R.S. &c.*

In this paper the author shows by a number of experiments that quicklime exercises on most animal and vegetable substances a preservative, and not a destructive power according to popular belief; and, consequently, that it may be used with propriety, not for the purpose of consuming dead bodies, but for that of arresting their putrefaction and the disengagement of offensive gases.

When the lime becomes converted by the absorption of carbonic acid into carbonate of lime, it no longer possesses the same antiseptic quality: hence, if moisture with atmospheric air be present, the bodies buried in lime will undergo change and decomposition, but this slowly and gradually, as the lime itself becomes neutralized and inert.

On the Blood of the Common Earthworm. *By* JOHN DAVY, *M.D., F.R.S. &c.*

The fluid in question was collected from the cardiac organs, and was carefully freed from the perivisceral fluid. It was found to have an alkaline reaction,—to be coagulable by heat and by nitric acid, very much in the same manner as the serum of the blood of the mammalia,—to contain red corpuscles (these, taking the average, about $\frac{1}{14000}$th of an inch in diameter), and to yield, when chemically examined, traces of iron.

Possessing these qualities, the author has come to the conclusion that this red fluid is blood, and, as such, that it performs a double function, one of nourishing, the other of aiding, by absorbing oxygen, in aërating the body. Its relation to the perivisceral fluid—that also probably a nutritive fluid—he has not attempted to determine.

On the Question whether the Hair is subject or not to a sudden Change of Colour. By John Davy, *M.D., F.R.S. &c.*

The conclusion arrived at by the author respecting this question is negative, partly founded on defective historical evidence, none of the instances adduced of sudden change, according to him, being of a satisfactory kind, and partly on physiological data, the human hair, after it has sprung from the bulb, the gland which secretes it, being "anorganic," destitute of any circulating fluid, and remarkable for its power of resisting change when exposed to the action of chemical agents.

The attempts made to support the popular notion that hair may suddenly, even in a night or in a shorter space of time, become grey, by reference to change of colour of the coats of certain of the mammalia, and of the plumage of certain birds on the approach of winter and of summer, are objected to on the ground that in all these instances the change of colour is, as far as he has been able to ascertain, associated with a change of hair and feathers, that is, with a new growth, the old being shed.

Observations on the Encephalon of Mammalia. By R. Garner, *F.L.S.*

In this paper the author adverted to the extreme doubt still dwelling in the minds of physicians and physiologists with respect to the functions of the different parts of the brain. He took up the theory that the cerebellum is not the organ of amativeness, as maintained by Gall, but the distributor of the motive impulse descending from the cerebrum. His proofs were derived from comparative anatomy, and from the development of the cerebellum at different ages, as well as from a remarkable case of disease. He also endeavoured to localise the sources of its different kinds of influences, whether they are exerted upon the head, trunk, or limbs, or in flexion and extension. The cerebellum seems to be as often a separator as a combiner of cerebral impulse; for instance, the *motores oculorum* are given off above the cerebellar connexion, and we have no power of separate action in these nerves, whilst it is the reverse in both respects with the *abducentes*. With respect to phrenology, he observed that its list of faculties and feelings is very complete, whilst one-half of the convolutions, their supposed seats, do not appear on the upper surface of the brain at all, or influence the form of the skull. He next endeavoured to prove the functions of the component parts of the brain, and traced the development of the convolutions from the smooth brain of the rodentia to that of the ape and man. The distinction and description of these folds is not without the pale of anatomy, and their consideration forms the transcendental plan of arranging the Mammalia. He made a few observations on the general form of the cranium. Females, he thinks, have by no means, comparatively speaking, low foreheads, but the reverse, at least centrally; their skull is also more lozenge-shaped, a little prominent at the sides. He thinks men of low or moderate stature have commonly an advantage in cerebral development; but the convolutions in a small brain are oftener richer or more numerous and tortuous in their divisions than in the other case; and some eminent men have had very small heads. With regard to the boat-shaped or long-head skull, from before to behind, and the rounder and broader form, the differences, sometimes perhaps national, may be in others only individual; the author thinks that the former variety has in some respects (the exact studies for instance) very frequently the advantage. Twins have been noticed by the author, one having the elongated head, the other the broad. In the case above alluded to of cerebellar disease, it was a cyst without any other lesion of the encephalon, and locomotion was greatly interfered with, unless the cerebrum was brought into action; the abducentes were paralysed, the motores not. The paper was illustrated with life-size photographs of brains of healthy persons of different ages, of a woman of a hundred, of a deaf mute, and of idiots and epileptics.

On certain points in the Anatomy and Physiology of the Dibranchiate Cephalopoda. By Albany Hancock.

The author confines his observations in this paper almost entirely to the so-called water-system, and to the blood-system; and, after entering at some length into the anatomy of the parts, concludes his remarks with the following summary, giving the results at which he had arrived, though in some respects they are not to be considered final.

First, That the so-called abdominal or visceral chamber, in the Dibranchiate Cephalopoda, is a veritable venous sinus, formed by the expansion of venous trunks; and that it is provided with proper walls.

Second, That, apparently, capillary vessels exist, uniting the arterial and venous branchlets; and that the blood-system is composed of vessels and sinuses with proper walls, therefore constituting a closed system.

Third, That the so-called water-system, for the ingress of water from the exterior, does not exist; but that the chambers to which this function has been attributed compose a diffused kidney—the glandular appendages in the renal chamber being for the purpose of eliminating peculiarly urinary matters, while the fluids pass off through the agency of the capillaries of the various organs that lie in the several chambers.

Fourth, That a rudimentary absorbent system exists in these animals, the intestinal veins assuming, in addition to their own, the function of lacteals, and the so-called fleshy appendages of the branchial hearts acting, probably, in the capacity of a general lymphatic system.

Fifth, That there is no pericardium properly so called.

Sixth, That the muscular fibre of the systemic heart is of the striated variety, as is also, apparently, that of the branchial hearts.

Seventh, That the cephalic arteries and those supplying the fins are provided with bulbous muscular enlargements, probably for the purpose of regulating the flow of the blood.

Eighth, That the surface of the brain of *Octopus vulgaris* exhibits inequalities resembling rudimentary convolutions, and that the pedal nerves arise by double roots; both conditions approximating to the higher standard of the Vertebrata.

Ninth, That the results of analysis of the nervous system corroborate the deductions derived from embryology as to the homological import of the parts.

On Nerves without End. By Professor Hyrtl.

On the Pneumatic Processes of the Occipital Bone. By Professor Hyrtl.

On Portions of Lungs without Blood-vessels. By Professor Hyrtl.

On Chloroform Accidents, and some new Physiological Facts as to their Explanation and Removal. By Charles Kidd, *M.D.*

The author held that "there is every reason to hope that, in consequence of more correct opinions now entertained in hospital practice on the administration of chloroform, the deaths from that agent will disappear altogether, as they have been manifestly diminishing in proportionate frequency during the last twelve months, now that these accidents are better understood." His conclusions were—"All which the author submits goes to prove that in place of attending solely to the pulse, as hitherto, those who administer chloroform should for the future pay equal attention to the respiration of the patient, and in case of accident direct their first attention to it. The corroborative facts as bearing on his former views, as explained at Oxford, which the author wished to submit, were the following:—1st. That from a large number of experiments since published on animals, there is now no reason to doubt that cardiac syncope is a mere accident. The death arises, as carefully observed in such animals, by a form of tetanic fixture of the respiratory muscles in the early stages of the chloroform administration; and the best means of saving the life of such a patient is founded on that view of such accidents, namely, by the immediate adoption of such means for resuscitation as artificial respiration, tracheotomy, with the intermittent 'Faradisation' electric current, to imitate or assist respiration. 2ndly. Respiration has its earliest point of departure, not from the phrenic nerve and diaphragm directly, but from certain fibres in the superior laryngeal nerve, which are distributed to the laryngeal mucous membrane, which seem to act in a reflex manner on the diaphragm—stopping its action if the action be too great, as from impure or pungent chloroform acting on the membrane, or possibly from idiosyncrasy; as it has been a long time observed, in France especially, that it is dangerous to administer chloroform where irritable larynx exists, or emphysema or other extensive lung-disease. That such irritation, under other circumstances, of other branches of the eighth pair produces permanent closure of the glottis till relieved by tracheotomy—a very formidable remedy no doubt, but one never to be lost sight of in accidents from chloroform."

On the Physical and Physiological Processes involved in Sensation. *By* J. D. Morell, *M.A., LL.D.*

When an appropriate stimulus is applied to any of the organs of sense, a feeling is produced in the mind which is termed, in the language of mental science, a sensation. A pin driven into any of the nerves which extend themselves immediately under the surface of the skin produces pain,—a ray of light falling on the retina produces vision,—a sapid substance put into the mouth produces taste, and so forth. Now it has always been a puzzle amongst mental philosophers to understand how it is that we can come to a consciousness of external objects at all. Theories without number have been formed, from the time of Plato downwards, to bridge over the gulf which lies between matter and consciousness, between objects of sense around us and the fact of sensation within us. This chasm in our knowledge we do not pretend wholly to fill. At the same time, so many facts bearing on the question have been brought to light by the progress of physical science on the one side and by physiology on the other, and so much has been added by the mental analyst, likewise from his peculiar point of view, that the distance between the outer world and our own inner consciousness has been vastly diminished, and the mystery driven back to that one point of connexion between the brain and the human soul which no analysis appears likely fully to solve. Let us attempt then to strip away all that is mixed up with sensation naturally, and all that is added to it by our subsequent mental activity, so as to analyse the bare fact itself and reduce it to its simplest elements. Looking to the physical and external parts of the process, we must consider, first of all, what it is that the nerves convey from the world without to the mind within. Let us take as an example the sense of hearing, as presenting the greatest degree of simplicity. We know, from the investigation of physical science, that the sole medium of sound is the atmosphere. Where there is no atmosphere, there can be no sound; and where the atmosphere is perfectly still, perfect silence is the necessary result. The real cause of sound, therefore, externally considered, is found in the motion of the atmosphere; and the variations in the acuteness or gravity of sound, we know by experiment, arise from the greater or less rapidity of the oscillations. The deepest note which the human ear appears capable of perceiving as a continuous sound is that produced by sixteen oscillations in a second; the acutest, that which is produced by about 48,000 oscillations in the same time. The differences in the quality of sounds arise, in like manner, from the peculiar way in which the atmosphere is affected by the object that sets it in motion, and the corresponding peculiarity of the atmospheric waves that reach the ear. What we really *sensize*, therefore, through the ear is simply the motion of the atmosphere, and nothing more. The human ear is an apparatus beautifully formed for receiving the vibrations on which all sound depends, and the auditory nerve conveys them, in some manner, to the sensorium. With regard to the way in which this latter effect is brought about we have as yet very little insight. The soft texture of the nerves, and the manner in which they are imbedded in the surrounding materials, would naturally suggest a total inaptitude for propagating vibrations in the ordinary sense of that term. It seems more probable that the flow of life through the body is accompanied with a constant thrill and movement in every part of the nervous system, forming what is technically termed the *cœnæsthesis*, or common sensibility; so that the outward oscillations do not so much originate wholly new vibrations as enter into conflict with the nervous action already going on, and give it that peculiar determination which is necessary to create any given sensation in the mind. This is, perhaps, as far as it is possible to go in our analysis of the physical process. How the vibration of the air comes into conflict with the living thrill of the nerve, and how the result of this conflict reaches the mind, we are at present unable to comprehend. It is one of those hidden secrets of nature which science has not yet been able to unfold. Turning from the sense of hearing to that of sight, a precisely similar analysis holds good. Here the vibrating medium is not the atmosphere, but a universally diffused ether which is set in motion by what are called luminous bodies. Just as atmospheric oscillations form the external cause, and sound the internal result, in the case of hearing, so in sight the oscillations of the light-bearing ether form the outward condition, and colour, in all its various shades, the inward result. Here, accordingly, as before, it is simply motion in nature giving rise to motion in the nerve-world with which we have immediately to do in vision; while, to keep up the analogy, it is the difference in the rapidity of the oscillations that creates all the infinite variations of hue. The red rays, it is calculated, require 458 billions of oscillations in a second, the violet rays 727 billions, and all the other colours and shades of the spectrum some intermediate number. That the phenomena of sound and sight spring physiologically out of particular states of the corresponding nerves is clear from the fact that pressure on the eye, or any artificial irritation, produces the perception of light as strongly as the normal impulses derived from the vibrating ether, and that any artificial excitement of the auditory nerve will produce noise in the head. Ghost-seeing often arises in the same way—that is, when the conditions of sight are brought about by the nerves being affected through some other than the ordinary and legitimate stimuli. Whatever, in a word, can affect the regular vital movements of the nerves, and put them into a condition at all similar to that produced by the proper external stimuli of sensation, will, of necessity, bring about similar phenomena of consciousness. We come next to the sense of feeling. This sense comprehends two apparently distinct series of sensations, namely, those of touch, properly so called, and those of heat. With regard to the latter, it has been pretty well established that the phenomena of heat originate in the oscillations of a subtle fluid similar to that of light. The sensation of heat may, therefore, be brought under the law of motion just as much as that of light or hearing, and may be regarded in every respect as analogous. The phenomena of touch, we know, are produced by impact in various ways; and it is just in accordance with the nature of that impact, whether harder or softer—more rapid or more slow—that the resulting sensations are determined. A blow is a sudden affection produced by the rapid motion of some object against a considerable surface of the body. Pressure is a more continuous affection of the same kind. A prick is the motion of some object against one minute point of the skin. If the act of pricking be repeated rapidly, it produces a feeling of burning, and, if it be very soft, at the same time of itching. An extremely light and gentle motion over the body produces tickling. In every instance the peculiar kind of sensation is determined by the nature of the motion and the consequent impact. The only two senses left, accordingly, are those of taste and smell. In both these cases the process by which the nerves are affected is of a chemical nature. The substances received upon the surface of the tongue or the internal membrane of the nostril are subjected to the action of saliva or mucus, and, being thus dissolved, produce a chemical action on the nerves, which gives rise to the phenomena of taste and smell. All chemical action, however, arises, as far as it can yet be ascertained, from certain relative movements in the ultimate atoms of bodies, and it is these movements which, in the case of taste and smell, really give rise to the peculiar sensations so designated. One striking proof of this is, that a similar atomic action can be produced by magnetism, and that various tastes, particularly that of phosphorus, can be produced by the introduction of magnetic plates into the mouth; thus most obviously proving that the phenomena of taste are really produced, like those of heat, by the motion of certain minute particles, whether of some magnetic fluid or of anything else, when subjected to chemical action. By these atomic movements the nerves are affected, just as they are affected by the infinitesimal oscillations of light and heat, so that the same law holds good throughout, and thus enables us to connect the phenomena of sensation universally with motion as its immediate external antecedent and exciting cause. Looking now from the physical side of sensation to the mental, we shall find that the view we have just taken solves or dissipates many of the difficulties in which the question has always seemed to be involved. First of all, it makes the external cause and the effect upon the nervous system quite homogeneous. Outward motion is the cause, inward motion is the effect. Instead of having the solid forms of the outward world standing as it were face to face with the nervous energy, and being obliged to consider how it is possible for two things so entirely heterogeneous to come into so close a state of mental action and reaction, we have now the whole problem reduced to two developments of motion: first, motion in the fluids around us; and secondly, a certain determination given, by their means, to the atomic movements or vibrations of the nerves. How the movements of the nerve-force are converted into those of mind-force we cannot say, any more than we can explain how it is that mechanical motion is converted into heat, or *vice versâ*; but the outward phenomena are traced, in the way we have now indicated, as far back to the inward consciousness as seems possible, without breaking through the last film of separation that divides the conscious from the unconscious world. Secondly, the theory we have adopted enables us to draw a clear line of separation between sensation (properly so called) and all the subsequent mental phenomena which attach themselves to it. Thus, taking the sense of hearing, we can now easily strip away every possible association which connects itself with what we hear, and understand that the sensation of hearing itself simply implies the nervous effect of certain atmospheric vibrations, and nothing more. Taking the sense of sight, we can at once negative the possibility of sensizing size, shape, thickness, distance, or any other of the properties of bodies: all we see sensationally is colour, as being the direct result in the consciousness of the luminous vibrations which affect the optic nerve. And so in like manner does every sense confine itself to one single and peculiar series of phenomena, which are not by any means to be confounded with the mental acts and associations afterwards connected with them. Thirdly, the same theory introduces unity into the entire sphere of sensational phenomena. The whole of these phenomena are reduced to the single principle of motion, as the invariable antecedent; this motion, as it exists in external nature, exciting a corresponding action in the nerves, and then, through the nerve-force, affecting the mind. Thus, then, we find, by the combined aid of physics and physiology, (1) that man possesses a nervous system pervaded by a force which can pass freely from every point in the human system to the centre, and from the centre to every point in the circumference; (2) that he is placed in a universe palpitating with countless millions of vibrations, of which vibrations the nerves of the different sense-organs are directly susceptible; (3) that the whole connexion which the mind has, or can possibly have, with the external world is formed by the motion of the fluids around us, or the motion of the particles of bodies that come into chemical contact with the nerves; (4) that the material universe, therefore, makes itself known to us entirely through the medium of motion; (5) that this motion expresses itself in the nervous system by modifying the regular vital action which is always going on there; and (lastly) that this modification of the nerve-force manifests itself to our consciousness in the varied phenomena of what we term sensation. Thus the world communicates with the consciousness wholly through motion as a link of connexion, and out of the experiences thus formed our whole intelligence is subsequently built up by the laws of mental development.

On Prison Dietary in India. By Dr. Mouatt.

The author commenced by giving a brief history of the successive dietaries in use in Bengal, and then proceeded to detail the results of an inquiry which had been made into the sanitary influences of the existing dietary. He stated subsequently the principles that should guide the formation of a prison dietary, applied those principles to the dietary in use, and concluded by suggesting the remedies necessary to correct the errors of that scale of food, without losing sight of the primary objects it is intended to fulfil, namely, to maintain the health of prisoners at the lowest possible cost to the State, so as, on the one hand, to avoid improper indulgences, and, on the other, to secure a sufficiency of food to preserve health and prevent disease. Facts and figures were produced to show connexion between the diet-scales and the mortality from diseases most nearly associated with the functions of digestion—dysentery, diarrhœa, scurvy, phthisis, and cholera, of which the connexion was believed to be very doubtful. The dietetic value of the chief articles used as food in the prisons of Bengal was given on the authority of the analysis propounded by Dr. Forbes Watson, and four different scales of diet were recommended: 1, for Bengalese and Assamese; 2, for natives of Behar, the North-west Provinces, and the Punjab; 3, for Coles, Sontals, Garrows, and Hillmen generally; and 4, for Mughs and Chinamen. The last-named were fond of cats, dogs, rats, or any animal food, and mere vegetable diet never satisfied them. The scales referred to were all for long-term convicts, and were stated to be the minimum to maintain health and strength.

On the Existence and Arrangement of the Fovea Centralis Retinæ in the Eyes of Animals. By Prof. H. Müller.

The fovea centralis and macula lutea have generally been regarded as a peculiarity of man and quadrumana. The physiological dignity of the spot, and the power to see an object at the same time with the two foveæ, seemed to secure to the organ of vision of these beings an exceptionally high position. But this is not true. I can say, for the moment, that the chameleon and at least many birds which possess the apparatus for optic accommodation so highly developed are also endowed with the delicate nervous apparatus represented by the fovea and the thicker parts surrounding it. The extent of surface which presents this peculiar organization is found sometimes so great, that a very considerable part of the retina may be compared to the macula lutea of the human eye. There is in this part of the retina of these animals the peculiar arrangement of the bundles of nerves, which are curved round, so that many fibres come into, but none pass over it. There is the accumulation of ganglion-cells, which form several layers in the circumference of the fovea. There is the peculiar conformation of the external layer of the retina, in which the elements sensible to light are thinner and longer than elsewhere; so that in the fovea this layer, necessary for the first reception of light, alone is thicker, while the other layers are attenuated. There is, finally, the oblique course of the fibres in the granular layer, which put in communication the enormous quantity of sensible elements in and next the fovea with the ganglion-cells in the neighbourhood. It is at the same time very interesting, that the two species of radial fibres in the retina of which I treated ('On the Retina,' 1856, p. 72), namely, of nervous and connective tissue, have in those animals a different course—in the granular layer the one sort running obliquely, the others running perpendicularly to the external surface of the granular layer. The fovea centralis is ordinarily to be found in the eyes of birds next to the posterior pole of the sclerotica, but sometimes excentrically therefrom towards the temporal part of the eyeball. In owls the excentricity is so great, that a common act of vision in the two foveæ is very reconcileable with the position of the eyes in these animals. In some mammalia, besides quadrumana, there exists at least an area centralis which approaches the arrangement of the yellow spot; the course of the vasa centralia, wanting in birds, at the same time becomes more like the human eye.

On the Influence of the Sympathetic Nerve on Voluntary Muscles, as witnessed in the Treatment of Progressive Muscular Atrophy by Secondary Electric Currents. By Professor Remak.

Physiological Researches on the Artificial Production of Cataract. By B. W. Richardson, *M.D., M.A.*

In the course of his remarks the author said that syrup of sugar injected into the circulation of a frog would produce cataract, and he exhibited a number of living frogs in which he had produced the disease by this means. The same injection produced the same result on both guinea-pigs and rabbits. An injection of common salt also acted like sugar, the only difference being that it produced harder cataract. If any of the soluble salts of the blood were present in excess, they would produce this condition. In 1838, at a meeting of that Society, Sir David Brewster had said that cataract was caused by the disarrangement of the fibres of the lens of the eye, and his theoretical notion had now turned out to be quite correct. In reply to a number of questions put to him, Dr. Richardson said that the lens might be cataractous without the patient being quite blind. Where a patient laboured under diabetes he had never seen a perfect lens. Von Græfe had demonstrated that one case out of every four of diabetes was accompanied with visible cataract. He (Dr. Richardson) had never failed in producing cataract in an animal by the means he had described. If they would give him an animal and the materials, he would tell them when the total eclipse of the eye of the animal would take place almost to a second. Occasionally, when sugar was present in the blood, the retina became affected. Frogs fed on sugar would become cataractic, but in animals that had active digestive organs the condition was not so easily produced. He had fed an animal on sugar for six weeks without producing any marked effect. After he had produced cataract in an animal, he could cure it. The cataract he produced in the frog and the cataract in the human subject were the same, with this exception, that in the human subject the exciting cause, the production of sugar, was constantly going on, whereas in the frog experimented on the effect was temporary.

Physiological Researches on Resuscitation. By B. W. Richardson, *M.D., M.A.*

The modes of death to which alone the author's remarks applied were such as involved no organic lesion, and had not extended to putrefaction or coagulation of the blood; and by death he meant cessation, not of respiration only, but also of the heart's action. As to coagulation of the blood, 700 observations had convinced him that it did not usually take place for twenty minutes after death. The modes of resuscitation he dwelt upon were—1, artificial respiration; 2, galvanism; 3, injection into blood-vessels; and 4, artificial circulation. Amongst the conclusions, stated as the results of many experiments, were these:—that artificial respiration is useless if the heart's action has ceased; that the heart's action may be prolonged by artificial respiration in a temperature of 130 degrees, where it would cease at once in an ordinary temperature; that when the heart has ceased to act in these cases, the right side of the organ is full of blood, and the left nearly empty; that then the column of blood which should pass from the right side to the left is broken, the hydrostatic law is violated, the two sides of the heart are in opposition, and the right side has not only to get over the weight of the column of blood, but also the contractile power of the left side—a thing it cannot do; that galvanism applied in any way to stimulate the heart hastens the cessation of the heart's motion, and that galvanism cannot be applied in any known way to resuscitate without injury; that injection of water at 130° Fahr. into the large blood-vessels of a dog will produce the muscular actions of life an hour after the muscles have been rendered torpid by prolonged galvanism, and two hours and a half after death; that this result, however, is not useful for the real recovery of life; and that the great desideratum now is some simple mechanical means of effecting artificial circulation. Dr. Richardson showed an apparatus of his own by which artificial circulation can be brought about, but not, unfortunately, without opening arteries too large to make the process useful. In cases of suspended animation, he recommended that if any respiration, however feeble, exists, no attempt should be made to interfere with it; that the patient should be placed in a dry atmosphere, at 130° of heat; that artificial respiration should always be set up where no breathing exists, as it is possible there may still be some cardiac motion; that electricity and galvanism are worse than useless; and that injection of arterial blood into arteries might be useful in many cases, if such blood could be obtained.

On the Cervical and Occipital Vertebræ of Osseous Fishes.
By Charles Robertson, *Demonstrator of Anatomy in the University of Oxford.*

The author gave a description of the cervical vertebræ and their appendages in a few osseous fishes not before described, and important in considering the vertebral theory. He then proceeded to show that the same kind of modifications are met with in the grouping of the elements of the occipital segment of fishes and in the skull, as in the vertebral column the same elements are not invariably present, but are subject to variations. The conclusions arrived at were these:—1. The partition-wall of the cranial cavity protecting the cerebellum is not invariably formed by two pairs of neurapophyses, exoccipitals, and epiotic: when the exoccipitals take a large share in the formation of the cranial walls, the epiotic are excluded; and when the epiotic are large and admitted into the cranial walls, the exoccipitals are excluded. 2. The neural spine is only present in the active species which have a large cerebellum to protect, and it is never divided. 3. The detached petrosal of Professor Owen is found in all species having the pectoral fin attached to the occipital segment, and always receives the lower prong of the suprascapula. The paper was illustrated with photographs of the skulls and vertebræ alluded to.

On the Connexion between the Functions of Respiration and Digestion. By George Robinson, *M.D., Newcastle-on-Tyne.*

In a paper "On the Nature and Source of the Contents of the Fœtal Stomach," communicated to the Royal Society of London in 1847, and published in the 'Edinburgh Monthly Journal of Medical Science' in the same year, I described certain observations on the contents of the stomach in fœtal and newly born rabbits, which seemed to me to prove the existence of a direct connexion between the function of respiration and the secretion of the gastric juice. I am not aware that the vital law thus indicated has yet received much attention either from physiologists or medical practitioners; and as I believe it to be one of some importance in the animal economy, I hope to be excused for now desiring to submit it to the consideration of this Association. The facts which, in my opinion, establish this principle are very simple, and can readily be examined by any one.

Immediately *before birth*, the stomach of the fœtal rabbit contains a dark-green, viscid, highly albuminous liquid, which scarcely affects litmus-paper; but after respiration has been established a few hours, the same substance is found firmly coagulated, and the whole contents of the stomach are strongly acid. This formation of acid gastric juice does not take place immediately after birth; for I have then observed the lungs inflated, and the contents of the stomach nevertheless unchanged. The process of respiration must continue for a certain time—a few hours—before the coagulation of the albuminous matter by an acid gastric secretion is accomplished.

The chemical changes therefore which occur in the stomach of the rabbit consequent on the performance of respiration, and the very circumstance of a certain interval elapsing between the commencement of the oxygenation of the blood and the appearance of the proper gastric juice, seem to me conclusive as to the connexion between the latter function and the former.

Now assuming for the present the correctness of this principle, some interesting questions arise. If the secretion of the acids of the gastric juice be thus dependent on the oxygenation of the blood, to what extent is the formation of the other animal acids also influenced by the action of respiration? And if a certain degree of oxygenation of the blood be requisite for the natural secretion of gastric juice, will not defective oxygenation impair the quality of the latter liquid, and so tend to connect some forms of indigestion with the imperfect performance of respiration? In this way, the improved appetite and digestion which we often observe to follow change of residence may really be a direct effect of the more complete purification and oxygenation of the blood by increased exercise and the inhalation of a purer air.

I can only hope that these and similar questions will be studied by competent chemical physiologists, and that the result of their researches will be still further to establish the mutual relation and dependence of the great functions of life; for at the present time, when physiological and pathological inquiries are so intensely localized, it becomes peculiarly important to recall to mind the essentially compound unity of the living animal.

On the Anatomy of Pteropus. *By* Professor Rolleston, *M.D., F.R.S.*

On some Points in the Anatomy of Insectivora. By Professor Rolleston, *M.D., F.R.S.*

The author confined his attention chiefly to the mole, the shrew, and the hedgehog—the three species found in this kingdom. The subject, he said, enabled us to illustrate principles of first-rate importance. He gave a number of details as to the osteological, digestive, circulatory, generative, and nervous systems of the Insectivora, dwelling especially upon the instances of variability of organs not subservient to special habits which this family furnished, and upon the variations to be found in individuals belonging to the same species. Referring to Gratiolet's classing the Lemurs amongst the Insectivora, Dr. Rolleston said that this arrangement might seem to be justified by the fact that the Lemurs differed from other Quadrumana by their non-possession of the hippocampus minor and of an overlapped cerebellum, and by their possession of a large olfactory lobe. In these points, also, the higher apes resembled the human species, whilst differing from the lower members of their own family.

On the Homologies of the Lobes of the Liver in Mammalia. *By* Professor Rolleston, *M.D., F.R.S.*

In descriptions of the internal anatomy of rare animals, it is usually easy, even without the aid of figures, to compare the accounts given of the arrangement of their organs with the arrangement of similar structures in animals more familiar to us. To this statement the descriptions given of the lobes and lobules of a multifid liver form an exception; and the purport of this paper is to furnish the zoologist with a convenient and readily applicable system of nomenclature for the several divisions which the liver may be found to present in the mammalian series.

The umbilical view of the fœtus, preserved for us in the adult in the so-called "suspensory ligament," furnishes us with our first landmark. The lobe to which it is attached we may call the "suspensory lobe;" it is very commonly, though not in the human subject, trifid,—the suspensory ligament having one lobule to its left subequal with a second to its right, which is bounded in that direction by the cystic fossa where the gall-bladder exists, and this second lobule, the "suspensory central," having the third lobule lying upon its right, between the indentation (when it exists) for the gall-bladder and the free right edge of the entire lobe.

The "suspensory lobe" overhangs the two other lobes into which the mammalian liver is divisible. To the left it overhangs a lobe which is very rarely if at all deeply incised or indented; this lobe we would call the "left lobe." The lobe which it overhangs to the right is very frequently lobulated somewhat complexly. This "right lobe" is divisible into three secondary lobules, the "superior right lobule," the "right kidney lobule," and the "lobulus Spigelii." The "superior right lobule" is frequently in relation with the pylorus, and in some animals, as the rabbit, is deeply excavated for the lodgment of that portion of the stomach: immediately overhung itself by the right subdivision of the suspensory lobe, it again overlies the "right kidney lobule," which is very commonly either deeply fissured or greatly excavated for the reception of the organ after which it is named. The "superior right lobule" and the "right kidney lobule" are often found to be fused into one mass in animals such as the hedgehog, *Erinaceus europæus*, and the long-eared bat, *Plecotus auritus*, in which they are usually distinct. Lastly, we have the "lobulus Spigelii," which (with two exceptions in the Marsupial series, viz. the *Phalangista vulpina* and the *Macropus giganteus*) we have found to be more directly in connexion with, and sessile upon, the "right kidney lobule" than upon any other portion of the liver. The bile-duct and the afferent blood-vessels of the liver pass in front of the origin of this lobule. It may effloresce into two processes distally and to the left, one of which may pass before and the other behind the cardiac end of the stomach, as in *Mus decumanus*; or it may give off a process near its origin and towards the right, which may interpose itself between the "right kidney lobule" and the "superior right lobule," as in the shrew, *Sorex vulgaris*.

In the nomenclature suggested by M. Duvernoy (Ann. des Sciences Naturelles, sér. ii. tom. iv.), the left division of the suspensory lobe is named "lobe principal gauche;" but its diminished proportions, as compared with those of the "left lobe" in some of the Insectivora and lower Quadrumana, incline us to consider it as wholly lost in such livers as those of man and the ruminants, and to assign it, when it does exist, to the "suspensory lobe." Without, however, positively pronouncing upon its homology, convenience of description induces us to name it "left suspensory lobule."

It is proposed, then, to speak of the liver as divisible into three principal lobes, two of which frequently admit of further subdivision—at the most, however, into not more than three lobules each.

The "left lobe."

The "suspensory lobe," which may be divided into { a left suspensory lobule. / a central " " / a right " " }

The "right lobe," which may be divided into...... { a superior right lobule. / a right kidney lobule. / a lobulus Spigelii. }

On the Influence of the Season of the Year on the Human System.
By EDWARD SMITH, *M.D., F.R.S.*

The author said that he only proposed to give a brief outline of a series of observations he had made upon himself, and to mention one or two deductions he had drawn from these observations. The observations he had made were to show the variations of the vital actions in the human system, and his two principal inquiries referred—the one to the respiratory functions, and the other to the elimination of nitrogen. In reference to respiration, the amount of carbonic acid evolved varied from day to day with the cycle of the seasons. He had found that there was a definite variation in the amount of vital action proceeding within the body at the different periods of the year, and that this followed a well-marked course. Thus, at the beginning of June a fall commenced, and this continued and progressively increased through June, July, and August, until the commencement of September, when the lowest point was attained. After this period, in October an upward tendency was manifested, and it continued through October, November, and December, until January, when a point was attained from which there was little change in January, February, and March. In April and May the amount of carbonic acid evolved was yet further increased, until the point was reached whence he started. The extreme amount of change observed was a loss of three grains of carbonic acid per hour from the commencement of June to September; and the extreme quantities recorded were in May 10·26 grains, and at the lowest period between 6 and 7 grains. The rate of respiration, the quantity of air inspired, and the quantity of carbonic acid exhaled, followed the rule he had explained. It had been proved by several series of experiments that the rate of pulsation was increased by heat, whilst the rapidity of pulsation was the reverse of the rate of respiration. With reference to the evolution of nitrogen, the conditions were the opposite of those of the elimination of carbonic acid. The general results he had arrived at were, that there was a greater amount of fluid evolved in the summer months than in the winter. The carbonic acid evolved decreased with the increase of temperature. On a sudden increase of temperature there was a large decrease of vital action, and on a fall of temperature there was an increase of vital action. The greatest growth of animals would occur at that period of the year when there was the largest amount of vital action; and in this respect they were connected with the vegetable kingdom. He believed that it was a fact with regard to the growth of children, that they grew at a greater rate in spring than in winter. From facilities which the Registrar-General had afforded him, he had ascertained that a much larger number of those children born at the latter part of the summer died within a year of birth than took place amongst those born at other periods of the year. The children born in the winter and spring periods were less subject to disease, and in all probability had stronger constitutions than those born in the summer season. These variations in the increase and decrease of the vital power of the system seemed to him to be the origin and the cure of diseases, especially those that were chronic. All epidemics to a large extent, in whatever part of the world they occurred, took place at the period when the human system was decreasing in vital action. This rule applied to cholera especially, which generally attained its greatest height in July and August, in October diminished, and in November disappeared.

On the Action of the Eustachian Tube in Man, as demonstrated by Dr. Politzer's *Otoscope. By* J. Toynbee, *F.R.S.*

From the time that the celebrated anatomist, Eustachius, in the 16th century, discovered the tube leading from the cavity of the fauces to that of the tympanum, this Eustachian tube has been usually described as constantly open, and the air in the two cavities has consequently been looked upon as constantly continuous. Although Mr. Wharton Jones in 1841, and M. Hyrtl in 1845, spoke of the faucial orifice of the Eustachian tube as having "the property of a weak valve opening either way," their opinion did not alter the views entertained by physiologists respecting the functions of the Eustachian tube, and its constantly open condition was considered essential to the due performance of the function of hearing.

In the year 1853 I laid before the Royal Society a paper, the object of which was to demonstrate, *firstly*, that the faucial orifice of the Eustachian tube is always closed, except momentarily during the act of deglutition or when air is forcibly blown through it; *secondly*, that the Eustachian tube is opened by the muscles of the palate, the *tensor* and *levator palati*; *thirdly*, that, contrary to the preconceived opinion of physiologists that "if the Eustachian tube is closed the hearing is lost at once," in order that the function of hearing may be duly performed, it is absolutely requisite for the Eustachian tube to be closed, otherwise the sonorous undulations, which ought to be confined to the tympanic cavity in order that they may be concentrated upon the *membrana fenestræ rotundæ*, are lost in the fauces, and the sounds from the fauces also enter the tympanum and produce the most distressing discord.

In proof that the faucial orifice of the Eustachian tube remains closed after the act of swallowing, the experimenter has but to swallow some saliva while the nostrils are closed by the finger and thumb: a sensation of pressure is produced in each ear, which disappears only when the act of swallowing is again performed without the pressure of the nose. It is also well known that unless the act of deglutition be frequently practised during the descent in a diving-bell, so that the Eustachian tube may be opened and air allowed to enter the tympanum, great deafness and a feeling of pressure in the ears are produced. Further, in cases where the membrana tympani is lax, it is seen to move outwards when air is blown into the tympanic cavity, and it returns to its natural position only on the act of swallowing being performed.

In order to demonstrate this function of the Eustachian tube, and also to diagnose its condition in disease, I suggested the use of an otoscope, consisting of an elastic tube about eighteen inches long and a quarter of an inch in diameter, each end being tipped with an ebony tube. Upon the introduction of one end of this tube into the ear of the experimenter, while the other is placed in that of the person experimented upon, if the latter distends the tympanum by a forcible attempt at an expiration while the nose and mouth are closed, the air is heard to enter and to distend the tympanum, and the cavity remains distended until the act of swallowing is performed, when the drum is heard to recede as the air makes its egress.

The views on the physiology of the Eustachian tube advanced by me before the Royal Society having attracted the attention of Dr. Politzer of Vienna, that gentleman performed a series of experiments with the object of testing their accuracy. The result is that Dr. Politzer came to the same conclusion as I had done, and he invented a simple and ingenious instrument, by means of which the action of the Eustachian tube can be seen. This instrument, which I have called Dr. Politzer's otoscope, consists of a rounded portion of cork or india rubber, about an inch and a half long, and about half an inch in diameter; in the centre of this is a glass tube about two lines in diameter, which externally is disposed in the form of an elbow. When used, the rounded and free portion of the cork or india rubber is moistened, and introduced into the external meatus, care being taken that it fits, so as to prevent the outer air from passing between the instrument and the walls of the meatus. When this has been accomplished, a drop of water is allowed to enter the tube so as to fill half the elbow, and to be on the same plane in each portion of it. The person experimented upon is now to close the nose with his finger and thumb, and (the mouth being shut) to force air into the tympanum. Immediately this takes place, the water is seen to descend in the inner portion of the elbow and to ascend in the outer portion. The finger and thumb are now to be removed from the nose, when no movement of the water is observed to take place in either elbow; but as soon as the act of swallowing is performed, the water is observed to return to its original position, the drum having receded on the opening of the Eustachian tube.

On the Physiological and Medicinal Properties of Sulphate of Aniline, and its Use in the Treatment of Chorea. By Dr. J. Turnbull, *Liverpool.*

The author observed that medical men had not acquired a knowledge of new remedies commensurate with the improvements which had been made in other branches of medical science. The progress of organic chemistry had brought to light many new bodies worthy of investigation, and there could be little doubt that many of them would, if their properties were examined, be found to prove remedies of utility. The artificial alkaloids were a numerous class, and from their resemblance in chemical constitution to the vegetable alkaloids, it might reasonably be expected that some of them should have powerful and useful properties. He had been led to make trial of the sulphate of the artificial alkaloid, aniline, in cases of nervous disorder, and had treated with it successfully six cases of chorea, or St. Vitus's dance. In regard to its physiological action, he stated that aniline appeared to act directly on the nervous system as a sedative. The most remarkable effect, however, which it produced was a transient alteration in the colour of the skin and lips, which became of a bluish hue; and this he attributed to oxidation of the aniline and the formation of a colouring-matter in the blood. As a therapeutic agent, he expressed the opinion that it would be found by the profession to be a valuable new remedy.

GEOGRAPHY AND ETHNOLOGY.

On the Connexion between Ethnology and Physical Geography. By John Crawfurd, *F.R.S., President of the Section.*

It has been the practice of my predecessors to open the meetings of this Section by a short address, and I gladly follow their example, choosing for my subject one which I hope you will consider suited to the occasion—the connexion between ethnology and physical geography. Man will be found savage, barbarous, or civilized, in proportion to the quality of the race to which he belongs, and to the physical character of the country in which his lot has been cast. Beginning with the conditions least favourable to his progress, and rising to those which are most auspicious, I proceed at once to illustrate this principle by a few examples: such a step may perhaps be useful in showing the scope of our science—the knowledge of the earth considered as the habitation of man. Mere intemperance of climate, independent of any other obstacle, is sufficient to prevent man from making any advance towards civilization, and to hold him permanently in the savage state. The condition of the inhabitants of the Arctic, sub-Arctic, Antarctic, and sub-Antarctic regions are examples. The Esquimaux is the most striking: dwelling where the year consists but of one day and one night, where snow and glaciers are substituted for the green earth, where no plant yielding food for man will grow, and, save the dog, no domestic animal live, advancement is impossible. The Esquimaux alone can live in such a region, and this only as hunters and fishermen, leading a nomadic life over its vast surface. Under such adverse circumstances, we only wonder at the progress they have made in the arts, with stones, bones, sinews, skins, and drift-wood their sole appliances.

There are lands, indeed, which, from mere inclemency, seem incapable of supporting human life at all, and which seem never to have been inhabited. The islands of Spitzbergen and Nova Zembla within the Arctic, and New Shetland within the Antarctic Circle, are examples. Even more temperate Iceland had no aboriginal inhabitants, and was unpeopled until colonized about 1000 years ago, and this by one of the most highly-gifted races of man—the same which twice conquered France and England.

I take my next illustration from a country of a very different character, Australia. The great mass of this continent lies in a temperate region, with well-marked seasons, and the rest in a tropical one. The climate of that portion of it which has been tested is one of the finest in the world, and the land is not encumbered with forest, always so formidable an obstacle to the early advancement of civilization. With these exceptions it possesses no peculiar advantages: it has no great range of high mountains, and hence no great navigable rivers, while, from the same cause, a vast extent of its surface is an arid desert of sand. Compared to its area, it has but a small extent of coast-line, because little indented by gulfs, bays, or inlets, and hence it is wanting in facility of intercommunication. It contained no native plant available to cultivation for human food, and no native animal amenable to domestication, the dog excepted, of small value in such a climate. Under such discouragements, and without communication with strangers, any advancement in civilization would have been impossible, even had its native inhabitants been of the most highly-gifted races of man. Mentally and physically they are, on the contrary, among the feeblest, consisting of hordes of black, ill-formed, unseemly naked savages, possessed of no arts, except those which enabled them to maintain a bare existence from the spontaneous productions of the earth or the water.

Equal in extent to China, the whole population of Australia did not, probably, exceed in number that of a single town in that empire. Little more than seventy years ago this distant and unpromising land was selected as a place of punishment for English felons; in due time it was found excellently well adapted for the sheep, although no native animal of the family it belongs to existed in it, and chiefly by its help the population of the strangers rose to half a million. Ten years ago it was found to be rich in gold, a fact which the natives had not discovered; and if they had, the precious metal would have been of no more value to them than the quartz rock which contains it. The gold has doubled the civilized population, and, with the wool of the sheep, is exported, to the enrichment of the colonists and the world at large, to the yearly value of fifteen millions. At even less than its recent rate of increase, Australia will, in a century's time, contain a population equal to that of the United Kingdom,—a wealthy, proud, and formidable nation of Anglo-Saxons—mighty conquerors and troublesome neighbours.

The tropical Andaman Islands, in the Gulf of Bengal, are an example of a land even more inauspicious than Australia itself. With the exception of external form and of climate, not, however, specially favourable, every other condition indispensable to human progress seems here wanting. It produces no plants fit for human food, and not one animal amenable to domestication—except, perhaps, the hog; indeed, with the exception of these and of apes and reptiles, hardly any large animals at all. The aborigines are a small, feeble race of black negroes, in physical form much below even the unpromising Australians. In the same Southern Hemisphere with Australia lies a land of less extent, but of far higher attributes than Australia, New Zealand. The two islands which mainly compose it lie within the similar latitudes with Italy, Greece, and the Archipelago. The soil is fertile, and high mountains secure a perennial supply of water. With these natural advantages, however, they possessed when discovered no native plant amenable to cultivation, or animal capable of domestication; for the yam, the batata, and the taro were imported exotics; and the dog—for want of suitable food, small and few—also an imported stranger. The inhabitants themselves were emigrants from the intertropical isles of the Pacific, as attested by the identity of their physical form and language with those of these islands. For lack of animal food—for they had destroyed the gigantic struthious birds of their country before they were known to Europeans—the New Zealanders betook themselves to eating one another, and were the most open and avowed cannibals on record. They would have been even more abject savages than they were, had they not brought with them the above-named cultivated plants. Notwithstanding this, our experience of the New Zealanders has shown them to possess more courage and capacity than Europeans have ever found in any other wild race. In these qualities they are a contrast to the feeble and effeminate people of the tropics from whom they sprang—a difference of character which can hardly have arisen from any other cause than that of a comparatively rigorous climate, necessitating exertion.

The vast continent of America, temperate, tropical, and equatorial, naturally possesses many of the essential properties requisite for the promotion of a high civilization—deeply indented coasts, high mountain-chains, and the greatest rivers of the world, with lakes equivalent to inland seas. It was for the most part covered with deep forests, unconquerable by the feeble efforts of savages, clear mountain plateaux and prairies being the exceptions. Instead of the many cereals of the Old World, it had but a single corn. It had no domestic beast of draught, and virtually but a single beast of burden, of about one-sixth part of the power of the camel, and even this one confined to a mountain region, for which alone it was fit. But the greatest defect of America consisted in the race of man—below the negro of Africa in physical strength, and below the Malay in intelligence. The same race, with inconsiderable varieties, pervaded the whole continent from Terra del Fuego to the confines of the Esquimaux. The highest civilization reached by the American race was that which existed on the high plateau of the Andes but even that was far below the degree which had been attained by second- and third-rate nations of Asia—the sufficient proof of which is, that the Mexicans and Peruvians had not invented letters, nor discovered the art of making iron malleable, as had all of these. In that portion of America extending from the great chain of lakes to the Gulf of Mexico, where about two centuries and a half ago savage hunters alone wandered, there now exists, planted within that comparatively brief period, an Anglo-Saxon population as numerous as that of the country which colonized it, and of the same rank of civilization,—a fact which attests beyond all question the natural capacity of this region for developing the highest powers of man. This great and prosperous people imitates the country from whence it sprang in all things, virtues, vices, and follies. In obedience to this example it is at the present moment shedding its blood and wasting its wealth to no rational purpose.

The huge mass of land which we call Africa, extending over seventy degrees of latitude, although almost an island, has a coast less indented than any other of the great quarters of the globe. It has no high chain of mountains comparable to those of Europe, Asia, and America, and hence no great navigable rivers like theirs. It wants also their inland seas and great lakes. Much of its area consists of wild sandy deserts, and much of primeval and perennial tropical forest, more difficult of transit than the sandy desert itself. These natural obstacles are hindrances to intercommunication, and therefore to social progress. The races of man which inhabit Africa correspond with the disadvantages of its physical geography. Taking the capacity to invent written letters, to construct durable architectural monuments, and to form powerful states as tests of capacity for civilization, Africa may be briefly sketched. To the north of the chain of the Atlas and bordered by the Mediterranean, we have a narrow slip of land in climate and production far more European than African. The aboriginal people of this region, the Numidians and Mauritanians, the ancestors of the present Kabyles and Berbers, were in physical form and mental endowment more European, or perhaps Asiatic, than African. The countrymen of Jugurtha had invented letters, built durable monuments, and acquired such military skill and power as to enable them to defeat Roman armies. Their territorial limits, however, were too narrow, and their political skill too small, to enable them to construct an empire, and for 2000 years they have been subjugated by a succession of invaders. Egypt, like Barbary, has the advantage of a temperate climate, and of the peculiar and perennial fertility conferred by the Nile, without which its narrow valley would, like the country on both sides of it, be a mere desert of sand. The race which inhabited it was less European or African than Asiatic, and in capacity bore a considerable resemblance to Chinese. In so favoured a locality, and with such a people, an early social advancement was inevitable; but the Egyptian civilization was not a vigorous or an enterprising one. The Egyptians were a home-keeping people, who never left their own country, and who, unable to defend it, have been subdued by a succession of invaders for now thirty ages. Had the Jews, a people far more highly endowed, been sufficiently numerous and powerful, which their poor and limited territory forbade, I am of opinion that instead of the bondsmen they would have been the masters of the Egyptians. After referring to the Nubian and Abyssinian races, he continued:—

From the southern limits of the Sahara to the extremity of the continent, Abyssinia excepted, but the great island of Madagascar included, no race of man exists that has invented letters, built durable architectural monuments, or founded powerful commonwealths. Of the races inhabiting this territory, extending over twenty degrees of latitude, by far the most numerous and to us the most interesting is the Negro, too well known to need any description. Possessed of great bodily strength and power of supporting toil, the history of the Negroes would seem to show that their understandings are not quite in proportion to their physical qualities. No systematic and consistent form of religious belief has ever originated with a Negro people, and the object of their belief is merely a mischievous magic. This inferiority of the Negro can only be satisfactorily attributed to lack of mental power. It is this inferiority, combined with eminent capacity for mechanic labour, that has induced the powerful among themselves to make a trade in the weaker, just as other races do in cattle, and which has seduced foreign nations in all ages to engage in the hateful traffic, to abstain from which demands an amount of moral restraint not yet attained by all the nations of Europe, and reached by none of those of Asia. 10,000,000 of these negroes are now in the New World and its islands, 7,000,000 of whom are slaves, to the great detriment of civilization, whether as regards the slave or his owner.

The great Malayan and Philippine Archipelagos afford many striking illustrations of the connexion between physical geography and ethnology, and I shall adduce a few examples. The Island of Java, of volcanic formation, has a range of high mountains extending from one end to the other. These supply rich plains and valleys with an abundant perennial irrigation, making this island one of the most fertile spots on the globe. In form, Java is a long narrow island; and although of half the size of Britain, no part of it is above fifty miles distant from the sea. Its peaceful and docile inhabitants, at present about 12,000,000 in number, have immemorially been in possession of letters of their own invention, and their country contains beautiful architectural monuments, while the political institutions of the Javanese prove by their results that they gave no inconsiderable amount of protection to life and property. After referring to the contrast shown by Borneo, another of the islands of the Archipelago, owing to its physical inferiority, he continued:—

The Malay peninsula, fully double the size of Java, with some advantage over it in shape, is generally of the same geological formation with Borneo; and as to minerals, it is rich in tin, iron, and gold. Like Borneo, it is covered by a dense tropical forest, always, as already stated, a serious and almost insuperable obstacle to the early progress of civilization. The native inhabitants are of the same race as the Borneans, but even lower in the order of civilization. Immediately east of Java are two small islands, Bali and Lombok, of the same geographical formation with that island, and, like it, having high ranges of mountains, the source of an abundant irrigation. Of the same race with the Javanese and Borneans, they have letters and monuments, and are virtually in the same state of advancement as the Javanese. Their population, computed at 1,000,000, is probably equal to that of all Borneo. The Malayan peninsula and some of the Philippine Islands exhibit a phenomenon unknown in any other part of the world—that of two distinct races of men, dwelling, but not intermixing, in one and the same land. These are the Malayan and a diminutive Negro, the latter leading an erratic life in the mountains, in as wild a state as that of any tribe of Americans, and the first with more or less civilization—even possessing a knowledge of letters. The islands of the Pacific, from New Guinea to the Feejee group, are peopled by negroes, always in a lower condition than the brown race which peoples the neighbouring islands, and the greater number of their inhabitants are certainly cannibals. Voyagers have noticed one favourable distinction between these negroes and the brown and more civilized race—they were always found honest, while the fairer people were invariably incorrigible thieves. The brown race in question, proved, by identity of physical form and language, to be the same from the Sandwich to the New Zealand Islands, were found on their discovery (the last-named islands excepted) in a higher state of civilization than any native people of America, except those inhabiting the plateau of the Andes. This advancement they owed to the possession of such cultivated plants as the yam, the batata, the bread-fruit, the taro or caladium, the cocoa-nut, and the sugar-cane, with such domestic animals as the dog, the hog, and common fowl. But, like the rudest Americans, they had no domestic animals for labour, and were ignorant of iron and every other metal. Notwithstanding, therefore, a fertile soil and mild climate, cut off, as they were, from all intercourse with more civilized strangers, they could not be expected to have gone beyond the point of civilization which they were found to have attained when Europeans first saw them. Such of them as had no domestic animals, or not an adequate supply of them, were undoubtedly cannibals. The people of the Sandwich Islands—now Christians—certainly were so but eighty years ago.

Advancing to higher civilizations, I may begin with the Persian. Persia is a plateau generally rising about 3000 feet above the level of the sea. The greater part of it is within the temperate region, but a considerable portion subtropical. It has many deserts and salt lakes. In these deserts the fertile spots, that is, those that are supplied with water, are few in comparison. To this general character, however, the lands bordering on the Caspian, copiously irrigated from a range of high mountains, are an exception, for they are eminently fertile. The Persian race is a peculiar one, and among Asiatics a highly endowed one, personally and intellectually. For five-and-twenty centuries, and probably even a longer time, it has been in possession of letters and the skill to erect durable monuments. But the physical geography of the country is certainly a serious impediment to a stable and lasting civilization, for it not only encourages the invasion, but the permanent settlement within its borders of pastoral tribes, still retaining their nomadic habits. These wandering tribes, differing in language and manners from the Persians, are estimated to amount to a fourth part of the population. This is as if one-fourth part of the population of England were to consist of armed gipsies. My next example is the country of the Hindus, a land which nourishes two hundred millions of men, but which, like much of Africa and of Australia; would assuredly have been but an arid desert, with pastoral tribes wandering over it, had it not been for the Himalayas and the Ghauts, the sources of those great rivers which have given it soil, irrigation, and means of intercommunication. Hindustan is almost as unbroken a mass of land as Africa itself, and more so than Australia; and the amount of this disadvantage may be estimated by the fact that its coast-line is less than that of Britain, of one-fifteenth part its extent. Throughout Hindustan the race of man is probably, in all essentials, the same, with such varieties only as prevail among Europeans, Negroes, and the red man of America. The Hindus are a black people, of a deeper tint than any other race of man, the African and Oriental Negro and Australian excepted. The form of the head and features is European—even of the highest type, the Grecian; but experience teaches us that there must be an essential difference in the quality of the two brains, although too subtle for anatomy to detect. There is, in fact, no rational foundation for the extravagant theory which would make Hindus and Europeans to be of one and the same race, under the absurd and hypothetical designation of Caucasian: twenty centuries of history belie the assertion. Above two thousand years ago the Hindus were, according to the measure of Asiatic civilization, a highly advanced people, and possessing the evidences of it in indigenous written language, architectural monuments, and institutions of some skill and great persistency.

We come next to the highest civilization of Asia, that of China, the joint result of superiority of race and favourable physical geography. The high mountain-chains of China, often rising to the snow-level, and chiefly lying to the west, are the sources of the great rivers which fertilize spacious alluvial plains, and nourish millions of men. It was no doubt in these plains that first sprang up the peculiar civilization which has spread over a region twenty times the extent of Britain, and numbering fully sixteen times its population. With respect to the quality of the race itself, it far exceeds all other Asiatic ones in bodily strength, in capacity for labour, in ingenuity, and in power of supporting vicissitudes of climate, for we find it thriving alike under the heat of the equator and the cold of the fiftieth degree of latitude. It is almost superfluous to add that their knowledge of letters, peculiarly their own, is of immemorial antiquity. For ages, too, they have had the capacity to erect great and enduring structures. Their foolish wall, to keep out the shepherds of Tartary, and compared to which, in magnitude at least, the Pyramids of Egypt are but mole-hills, was constructed two hundred years before the birth of Christ.

The superiority of their political institutions is proved by its fruits—a progress in the useful arts and an accumulation of wealth which have never existed in any other Asiatic nation. In China, as in India and as in the region which lies between both, we find rude, unlettered tribes, who, although of the same race as the Chinese, have not participated in their civilization. These mountaineers—for such they necessarily are—chiefly abound in the less favoured provinces of the west, where the great rivers have not yet attained the magnitude which confers fertility and means of internal communication. From the Sea of Japan to the Caspian there exists a vast region, for the most part steppes and sands. This is the native country of the Tartars and Turcomans—of men who, for the most part, dwell in tents, and whose normal condition is as migratory as that of birds of passage. Immemorially in possession of the horse, the camel, and the sheep, the very physical character of their country would seem to condemn them in perpetuity to the pastoral condition. The huge peninsula of Arabia, although a tropical or subtropical country, much resembles Tartary, in the frequency of its deserts and the fewness of its fertile or watered spots. The habits of its inhabitants, therefore, were generally pastoral, like those of the Turks and Tartars. The highest civilization which the Turks ever attained was in Eastern Europe and in Northern India; the highest which the Tartars reached was in China, and of the Arabs in Spain.

Europe is the quarter of the globe which, through the great advantages of superior physical geography and superior quality of race, has attained the highest measure of civilization. Its extensive seaboard, caused by deep gulfs and inland seas; its numerous lakes and rivers; its many islands, with a temperate climate, afford it means of industry, commerce, and intercommunication possessed by no other part of the world. The superiority of its races of man is attested by an experience of three thousand years. In the quality of these races among themselves there is, probably, no material difference; sufficiently proved by the fact that no deterioration follows their intermixture, as shown in the instances of the very bastard people whom we call French and English. The term Europe, however, is but a conventional and not a very well-defined one, and the advantages of physical geography and race which I have ascribed to it belong especially to the southern portion, always its only seats of high civilization. The sterile and oft ice-bound far North has never produced,and seems incapable of producing, a great and powerful civilization. Yet from the rigorous North has emanated one of the most highly-endowed races of man—that which overthrew the huge structure of the Roman Empire, which in later times conquered a large portion of France and the whole of Britain, and to which, above all other causes, is owing the vigorous civilization of modern Europe and Northern America. The vast superiority of the European over the other races of man, and especially over the precocious but soon stagnant races of Asia, need not be insisted on at length, and I shall confine myself to a few modern instances. Thus, but for the European race, the old and new world would have been unknown to each other: that race has conquered the whole new world and largely peopled it with men more civilized, more powerful, and far more numerous than its aboriginal inhabitants. But for the European race, China would have been known to the rest of the world only by report, and Japan and the great Indian Archipelago as unknown as America. While the European nations have virtually subdued all America, discovered and conquered a fifth quarter of the globe, Australia, and conquered and occupied a considerable part of Asia, no foreign race can be said to have invaded and permanently settled in Europe. The Turks conquered the weakest and most degenerate portion of Europe, and beyond this they have never succeeded in penetrating, notwithstanding many attempts. They have been in Eastern Europe about half the time that the Saracens had been in Spain, but, in the true character of an Oriental race, they either refuse or are unable to keep pace with the European races, and, now existing only by their sufferance, absorption or expulsion is their inevitable fate.

The races of Asia (and it affords incontestable evidence of incapacity and inaptitude) have borrowed little from Europe. I can quote but two notable exceptions—fire-arms and tobacco, both of which they promptly adopted on the first opportunity. They reject the printing-press, obstinately persevering in the slow and expensive manuscript which in Europe impeded the progress of knowledge 500 years ago. They very rarely use the mariner's compass, but steer along the shore, or trust to the stars and the monsoons. The European races have, on the contrary, borrowed freely from every country that had anything good to give. From Asia the list of our adoptions is large, for from it we have derived cotton and the cotton manufacture, silk and the silk manufacture, paper, without which the printing-press would be worthless, the sugar-cane and its extracts, tea, coffee, spices, and opium. Nor must the domestic fowl be omitted, for that valuable acquisition is of Asiatic origin. To America we owe the potato, maize, the cinchona, the tobacco, and the turkey, and to Asia and America jointly all our most valuable dyes. To Africa our obligations are smaller; but palm oil, the gallinæ, and the ass may be named with respect. As to the invention of written language and to monuments of a high order, the only parts of Europe which boast of having possessed them are Greece and Italy, which in the march of civilization had so long preceded all the rest. The nations of Europe, now the foremost in letters, were (the Runic characters excepted, which probably never extended beyond the priesthood) as ignorant of them 2000 years ago as were the Mexicans when first seen by Europeans. In this respect, as indeed in architecture, they have been but dextrous imitators. This is a striking contrast to the precocious races of Asia, many rude tribes of whom, less civilized than ancient Gauls, Germans, and Britons, have been in possession of alphabets of their own invention from time immemorial.

The most favoured parts of Europe, even those which are now the seats of the highest civilization, afford, like India and China, examples of civilization retarded through disadvantage of physical geography, without any proved inferiority of race. Our own island yields two signal instances, Wales and the Highlands of Scotland. Had the whole area of Britain been no better than they, it is quite certain that we could not have been what we are—powerful, opulent, populous, and great. Their inhabitants, compared with those of the fruitful parts of the island, were as the Gonds and Garrows of India to the Hindus, or the Myo-tse of China to the Chinese. From their courage and locality they were difficult to subdue, and their unavoidable poverty offered no temptation. It is only by slow degrees, and the influence and example of a more advanced nation, that a people so circumstanced is brought within the pale of civilization. The process is, at present, in rapid advancement in the mountains of Wales and Scotland, even to the extinction of their barbarous although masculine and forcible tongues; but it has taken eighteen centuries to bring the Welsh and Highlanders to their present state from that which they were in when Gibbon describes one of them (and the other was probably little better) as consisting of "troops of naked barbarians," who "chased the deer of the forest over cold and lonely heaths, amid gloomy hills and lakes covered with a blue mist."

Journey in the Interior of Japan, with the Ascent of Fusiyama. By R. Alcock.

The paper commenced with a description of the difficulties which the writer encountered in Yeddo, in the early part of his journey in Japan. A large retinue accompanied him. The journey was begun in September 1860. On their way they had to cross the river Saki on the shoulders of porters, who were made responsible for the safety of the passengers; if any accident occurred to the travellers, the men had nothing to do but to drown themselves, as no excuse was taken. At first their way up the mountain lay through waving fields of corn, succeeded by a belt of high rank grass. Soon, however, they entered the margin of the wood which surrounded the base, and which crept high up the side of the mountain. At first they found trees of large growth—goodly timber of the oak, the pine, and the beech. At Hachimondo they left their horses and the last trace of permanent habitations and the haunts of men. Soon after the wood became thinner and more stunted in growth, while the cork and birch took the place of the oak and the pine. Just before they entered the forest-ground a lark rose on the wing—the first the author had ever seen or heard in Japan. As a general rule, the birds had no song, the flowers no fragrance, and fruit and vegetables no savour or delicacy. In the wood-belt were deer, wild boars, and horses. They soon afterwards lost all traces of life, vegetable or animal. On their journey they rested a little in huts or caves, partly dug out of the side and roofed. There were eleven of these resting-places, which were one or two miles apart, between Hachimondo and the summit of the mountain. The latter half of the journey was the most arduous. On the top of the mountain was a yawning crater—a great oval opening with jagged lips, estimated at about 1100 yards in length, with a mean width of 600, and about 350 in depth. Looking from the mountain, the country below was hid by a canopy of cloud. The estimated height of the edge of the crater above the level of the sea was 13,977 feet, and the highest peak 14,177 feet. The Japanese who performed the pilgrimage were generally dressed in white vestments, which on the summit were stamped with various seals and images by the priests located there during the season. As far as the writer could learn, a very holy man, the founder of the Sintoo religion, took up his residence on the mountain, and his spirit was still held to have influence to bestow health and other blessings on those who made the pilgrimage. The volcano had long been extinct. The latest eruption recorded was in 1707; and the tradition was that the mountain itself rose in a single night from the bowels of the earth, a lake of equal dimensions appearing the same hour at Miaco. The time occupied by the ascent of the mountain was eight hours, and the descent was accomplished in little more than three hours. The party slept two nights on the mountain, and had greatly to congratulate themselves on the weather.

On Australia, including the Recent Explorations of Mr. Macdonald Stuart. *By the* Hon. J. Baker, *F.R.G.S.*

Mr. Baker gave a rapid sketch of the rise of the colonies of Australia and the habits of the aboriginal inhabitants. During the last year or two, the amount of gold discovered had rather diminished than increased; and a considerable number of hands were now employed in cultivating the soil who were previously engaged in the diggings. All other exports were gradually increasing, and only population was required to enlarge them to an almost unlimited extent. There were numerous rich mineral deposits, and many places in which cotton might be grown with advantage. There was not a more loyal people under the sun than the Australian colonists. Mr. Baker then gave a few extracts from Mr. Stuart's journal of his last expedition into the interior. After noticing the starting of the expedition, on the 2nd March, 1860, and the successive visits to Mount Hamilton, and Beresford, Williams, Milne's, Keckwick, and other springs, the character of the country at the West Neale, Frero, the Stevenson, Mount Humphries, the High Gum Creek, &c., the arrival of the traveller at a small gum-creek under Mount Stuart on the 22nd of April was referred to—that being found, from observation of the sun, to be the centre of Australia. A tree was there marked, and the British flag planted. It was a mistake to suppose that the flowers in that country had no smell, a rose being found with a sweet, strong perfume. Subsequent interesting adventures were sketched, and the third unsuccessful attempt of the traveller to make the Victoria River was alluded to, the journal concluding with the arrival of the party at Chambers Creek.

On the Mountains forming the Eastern Side of the Basin of the Nile, and the Origin of the Designation 'Mountains of the Moon,' as applied to them. By* Charles T. Beke, *Ph.D., F.S.A., F.R.G.S. &c.*

This paper was in continuation of the author's communications to the British Association in the years 1846, 1848 and 1851†.

It commenced by stating that the great additions made to our geographical knowledge since the date of the author's previous communications have all tended to establish the substantial truth of the opinions therein expressed.

In 1846 Dr. Beke described the Abessinian table-land as having its summit-line towards the sea-coast, and thence falling gradually towards the Nile; which river skirts the western flank of the high land, and is the *sink* into which all the rivers flowing over the table-land are received. The fall of the Nile is so small, that Dr. Beke then estimated its absolute elevation, in the fifth parallel of north latitude,

* Printed *in extenso* in the 'Edinburgh New Philosophical Journal' for October, 1861, new series, vol. xiv. pp. 240–254.

† See 'Report of the British Association' for 1846, Transactions of the Sections, pp. 70–72; Report for 1848, Transactions of the Sections, pp. 63, 64; Report for 1851, Transactions of the Sections, p. 84.

at not more than 2000 feet. It is now found that at Gondókoro, in 4° 44′ N. lat., the elevation of the bed of the Nile is only 1911 feet. On the other hand, the mountain-range of Eastern Africa, forming the anticlinal axis between the ocean and the basin of the Nile, which in 1846 could only be traced as far as 9° 30′ N. lat., may now be regarded as extending beyond the sixth parallel of *south* latitude, in a line running from N.N.E. to S.S.W. between the 40th and 35th meridians.

It was next stated that the snowy mountains, Kilimandjaro, Kenia, and Doengo-Engai, which in 1846 were unknown, are portions of this mountain-range of Eastern Africa, to which Dr. Beke attributes the name of the "Mountains of the Moon," the snows of which are described by Ptolemy as flowing into the two lakes of the Nile—the lakes intended being Tanganyika and Nyanza, recently discovered by Captains Burton and Speke.

With reference to the derivation of the designation "Mountains of the Moon" from the name of the country, U-Nyamwezi, in the vicinity of those lakes, the author showed in the first place how the Indian name of the island of Java—*Java-dvipa*—was translated into Greek Κριθῆς νῆσος or *Barley Island*, just as the Latin name of the Etruscan city and port of Luna was translated Σελήνη; though there is reason for believing that such significations did not belong to the words *Java* and *Luna* in their respective aboriginal languages, but were merely mistranslations, or rather misapprehensions, by the Indian conquerors of Java in the one case, and by the Romans in the other. In the same way, the native African name U-Nyamwezi, having become known to the Greeks through the Sawáhilis, or people of the coast, in whose language *mwezi* means *moon*, may have been supposed to have some connexion with the name of that planet.

Dr. Beke argued, however, that *Mwezi*, as a component part of the name U-Nyamwezi, does not necessarily mean *moon* in the aboriginal language of the country. All the Kafir tongues have certain prefixes, distinguishing singulars from plurals, adjectives from substantives, and one kind of substantive from another. Thus Ki-Nyamwezi is the language spoken by the Wa-Nyamwezi, which people dwell in the country called U-Nyamwezi, one of them being a M'Nyamwezi or Mu-Nyamwezi (whence our "Monomoezi").

It appears then that the root is not *Mwezi*, but *Nyamwezi*; and though it may be that the natives themselves never use the root without some prefix, strangers might not unreasonably do so, and even contract *Nyamwezi* into *Mwezi*, as the Sawáhilis and Arabs, according to Captain Burton, actually do; and from this contraction, the translation into the Greek *Selene* would have followed as a matter of course.

What the theoretical root may mean in the Nyamwezi language has yet to be ascertained. Meanwhile the rendering of U-Nyamwezi into "Possession of the Moon," or "Land of the Moon," may well be questioned. Should it prove to be erroneous, the designation "Mountains of *the Moon*," as applied to the great mountain-range of Eastern Africa in which are the sources of the Nile, will have originated in a mistranslation or misconception. Still, this well-known name has been in use during so many ages, that it could hardly be practicable, and certainly would not be judicious, to supersede it now.

The paper concluded thus:—"The entire eastern side of the basin of the Nile appears to be auriferous, the gold collected in various parts of it since the earliest ages being brought down by the tributaries of that river; so that there is reason to consider the Mountains of the Moon as a meridional metalliferous cordillera, similar in its general characters to the Ural and the corresponding mountain-ranges of America and Australia. . . . . Whenever the discovery shall be made in Eastern Africa of some of the chief deposits of that precious metal, the influx from all parts of the civilized world to the 'diggings' in the Mountains of the Moon will be such as to occasion a more rapid and complete revolution in the social condition of those hitherto neglected regions, than could be caused by commerce, by missionary labours, by colonization, or by conquest; as we have witnessed in other quarters of the globe, where the *auri sacra fames* has collected together masses of the most daring and energetic of human beings. We shall then, too, doubtless see in Eastern Africa, as in California and in Australia, the formation of another new race of mankind."

Notice of a Volcanic Eruption on the Coast of Abessinia. By Charles T. Beke, *Ph.D., F.S.A., F.R.G.S. &c.*

During the night of the 7th or morning of the 8th of May, 1861, a volcanic eruption took place from Djebel Dubbeh, in about 13° 57′ N. lat., and 41° 20′ E. long., accompanied by loud shocks resembling the discharge of artillery and immense clouds of dust. The noises were distinctly heard both at Massowah and at Perim, places nearly 400 miles apart, and the dust fell for several days over a vast extent of the Red Sea, and on the coast of Arabia as far as the mountain-range of Yemen. At Edd, on the Abessinian coast, a day's journey from Djebel Dubbeh, the dust was knee-deep, and its fall during the first day caused total darkness. The eruption continued at intervals for three or four days. There is no remembrance of any previous eruption. Djebel Dubbeh is distant about 230 miles, in a direction almost due north, from the great extinct volcano Aiyalu or Azalo, mentioned in Dr. Beke's paper "On the Mountains forming the Eastern Side of the Basin of the Nile;" and, like Aiyalu and also Kilimandjaro, it forms a portion of the mountain-system to which he attributes the designation of the Mountains of the Moon*.

Remarks on the Glacial Movements noticed in the Vicinity of Mount St. Elias, on the North-west Coast of America. By Admiral Sir E. Belcher, *C.B., F.R.A.S.*

Early in September 1837, Sir Edward's expedition ran down the coast of North America, between ports Etches and Mulgrave, in order to fix the position and determine the height of Mount St. Elias.

The icebergs which hung about the coast were much larger than those which he had seen in Behring's Strait and northerly, or off the mouths of the fiords in the vicinity of Port Etches. The icebergs presented a beautiful appearance.

He (Sir Edward) believed that in the upper valley of Icy Bay the lower bodies of the ice were subject to slide, and that the entire substratum, as frequently found within the Arctic Circle, was composed of slippery mud. In Icy Bay the apparently descending ice, from the mountains to the base, was in irregular broken masses, which tumbled in confusion. The motion was clearly continuous.

As to the causes which operated in producing the constant displacements of the glacier, and the protrusion of the bergs to seaward, many theories had been proposed. His (Sir Edward's) impression was that, whatever was the intensity of cold under which congelation had taken place, the actual temperature due to the ice was merely that of 32° Fahrenheit, and that self-registering thermometers, properly buried in ice or snow, subject even to the very low temperature of 62° 5′ below zero on the external skin of snow, only indicated the proper temperature of freezing water. Salt-water ice has a temperature or 28°.

In the very high latitudes of 66° to 76° north, the snow on the surface of the snow-clad elevations furnished sufficient water to undermine the lower beds of snow-ice, and bore a passage to the sea. However firm the crust might be in certain positions, a furious torrent had been at work beneath.

They were thus driven to the conclusion that the temperature of the earth must in some degree aid in keeping up a temperature sufficiently high to prevent the congelation of the water hidden from light or the sun's rays. The advance of vegetation was another proof, the ground-willow, saxifrages, and mayflower, and many other plants, producing their shoots before light caused the immediate expansion and colouring of the leaf.

The earth's temperature, acting on the lower portions next to the soil, aided in facilitating the travel of the slip of the snow-ice of which these glaciers were composed to lower levels. In all ice-formations might be noticed, at the season which followed the period of day frost or preceded the spring, a peculiar dryness, the result of evaporation of the superfluous water, attended by dense fogs. An ominous cracking was then experienced, which had been misrepresented by some of the first Arctic explorers as the breaking of the bolts of their vessels; no bolt was ever traced to have been so broken! He imagined that the soil on which masses of eter-

* Various particulars respecting this eruption are given by Dr. Beke in *The Times* of the 20th and 21st June, 24th September, and 16th October, 1861.

nal or eternally-shifting ice reposed must be, from never being exposed to the sun's rays, of a loose, boggy, or muddy nature, which facilitated slipping. The undermining facilitated cracking; and the very action of alternate freezing and thawing between the exposed surfaces, serving as aqueducts along the upper portions into which water would flow, must produce compact ice; and its power in that very action was quite adequate, by comparison, not only to remove ice, but even mountains of earth, provided the *point d'appui* be afforded.

It was evident with respect to the lower portions supporting Mount St. Elias, and which were subject to a summer heat which ripened strawberries, and was even more oppressive than we experienced in England, with the rapid thaws of the inferior levels, that repeated fracture and avalanches occurred. They must calculate on sudden tremendous concussive force, by the breaking away of whole ranges and their precipitation on the lower strata. His opinion was that the shocks of the avalanches communicated laterally had produced such fractures as had been noticed in those peculiar pyramidal forms near Mount St. Elias. These fractures, opened, were filled by water, which probably froze at night or when the sun was absent; and expansion drove the exterior masses, which were termed bergs, into the sea.

Such was his theory, founded on severe thought over a period of thirty-five years, under frequent contact with nature in actual operation.

The Great Earthquake at Mendoza, 20th March, 1861. *Extracts from a Letter written by* R. Bridge *to* W. Bollaert, *F.G.S.*

This catastrophe, the writer said, was treated by all as an earthquake; and, in the simple sense of the word, it might be classified as such, as the writer found in Mr. Bollaert's work on Earthquakes; but he distinguished between an earthquake and an internal irruption. The latter had evidently been the case at Mendoza, since its effects had been felt north, south, east, and west of the city, at Valparaiso, Coquimbo, in Chili, San Juan (north of Mendoza), and El Rosario (east of Mendoza), more or less equidistant. It was deficient in many of the characteristics of the earthquakes experienced in Chili, not having followed a line, no rain having fallen, and differences of time not having been observable. In fact, it appeared to have been simultaneous at all places; to have been an upheaving exclusively at Mendoza, and between that and the Andes. No volcano had, however, been found. The walls of the buildings had fallen, indicative of having been rent in every direction, none indicating any horizontal motion; indeed, had there been any such, the loss of life, estimated at 10,500 out of 13,000, would not have been so great, as the means of escape would have been facilitated by different fallings.

Cromleachs and Rocking-stones considered Ethnologically. By P. O'Callaghan, *B.A., Honorary Secretary to the Philosophical and Literary Society of Leeds.*

The author observed that no stone object of human veneration or superstition was so universally distributed over the face of the globe as the Cromleach. He then gave the Celtic derivation of the word, implying "crooked" or "inclining stone." He stated that, in consequence of its cumbrous obstruction, it has been for the most part removed or broken up in the cultivated parts of Europe, and was consequently now seldom seen but in desolate and secluded places, except where it had some peculiar local protection. From this circumstance, and especially from its rude and massive proportions, its construction was vulgarly ascribed to supernatural agency. After noticing the researches of Mr. Lukis and Sir R. Colt Hore, he said that it was now conceded on all hands that the Cromleach was originally a tomb or grave. He then described the manner in which he saw the Caribs dispose of their dead—doubling up the body into the smallest possible compass, and depositing it in a narrow excavation under one or more large stones, to conceal and protect it from the carnivorous animals of the surrounding forests. He thought that this was in all probability the most primitive, as it was the most natural, way of disposing of the human dead body, in man's savage state, all over the world. He inferred from this that the original Cromleach was of natural or accidental formation, and showed drawings of several which he said must have been thus formed. Two especially, of vast size, he thought were boulders dropped from ice-floes, which in falling upon others broke them, and remained ever since securely supported upon these rude props. They would then become ready-made and secure tombs, and would be continually used for such a purpose from the remotest ages.

On this supposition he thought that the relics of various and successive races, which are occasionally found in such Cromleachs, could be easily accounted for. He observed that it was not surprising that these large blocks of stone, so mysteriously disposed, should have produced a feeling of awe and veneration, and that they should even come to be regarded as objects of superstitious fear or ultimately of religious worship, such as that practised by the Druids. He said that he did not mean to assert that all Cromleachs were so formed; on the contrary, he thought that the greater number, especially of the smaller ones, were evidently artificial. All he meant to contend for was, that the original Cromleach was of natural or accidental formation, and used as a grave for countless ages before its artificial imitation, which ultimately assumed the form of a rude tomb. He considered that the universal distribution of the Cromleach should not be looked upon as a conclusive proof of an identity of origin of the various races of man, but rather as an indication of an identity of the instinctive resources of the human intellect under similar circumstances. He instanced the curious similarity, almost amounting to identity, of two stone hatchets in the Museum at Leeds, one of which was brought from Otaheite, and the other found, with ancient British relics, in a cave near Settle. He thought that when the materials of a Cromleach were light and easily displaced, the instinctive resource under such circumstances would be to conceal it under a mound of earth or stones, as the locality could afford. This he believed to be the true history of the original tumulus or cairn, which were the probable prototypes of those stupendous pyramidal structures of the more civilized Egyptians. He considered this a more natural explanation of those universal structures than the dreamy visions of certain ethnologists, who will only see in them the vestiges or landmarks of improbable human migrations, of which they offer us no more satisfactory evidence than the ingenious speculations of philologists, who find in language such a plastic material that they can mould it into any form to suit their own preconceived theories.

Amongst the other megalithic wonders, the erection of which has been popularly ascribed to supernatural agency, he remarked that none was more striking than the "Rocking-stone." He quoted a passage from Wilson's 'Prehistoric Annals of Scotland,' in which the writer graphically describes the engineering science and mechanical skill evinced in their erection. He thought that the theory advanced by him for the formation of the primitive Cromleach would easily remove all these mechanical difficulties. He observed that if the glacial flood, of which we have everywhere such manifest indications, had borne away upon its enormous ice-rafts vast blocks of stone, torn from the abraded sides of the valleys as they drifted through them, these masses of rock must have been all deposited on the bottom of this icy sea, on its increase of temperature and subsidence. Now, many of these floating boulders must, he thought, have fallen upon others, and rested upon the broken fragments, as in the instance of the Cromleach. He considered that it was not unreasonable to suppose that occasionally others may have been deposited quietly upon the very pivot of their centres of gravity, where they would remain curiously balanced, on the retreat of the waters. They would there naturally become objects of wonder and awe to the savage human creatures who first beheld them, and to all succeeding generations. He stated that the Phœnicians and Greeks assigned to the Rocking-stone divine power, and that the priests everywhere availed themselves of this superstitious fear. The author exhibited a sketch of the famous Logan Stone of Cornwall, to show how impossible it was to look upon it as the work of human hands. He described another sort of Rocking-stone, which he thought to have been formed by the gradual wearing of the narrow base of the overlying stone. In illustration of this latter idea, he exhibited a sketch of an "erratic block" near Settle, in the West Riding of Yorkshire, which is figured in Professor Phillips's interesting work on that county. He thought that it was not difficult to foresee that, in the lapse of time not very remote, the small base upon which this rock now rests securely may be scaled off by rain and frost, until the huge mass becomes detached, or poised upon a pivot so small as to allow it to oscillate as a Rocking-stone.

Notices on the Ethnology, Geography, and Commerce of the Caucasus. *By* CAPTAIN CAMERON.

The locality referred to was the Caucasian Isthmus. Hercules, Castor and Pollux, Ulysses, and other Greek worthies were all said to have done something towards opening the Caucasus to the enterprise of their countrymen. It grew to be pre-eminently a land of marvels. After reference to the ancient traditions of the Amazons, it was stated that the Caucasus had played its part in history, and especially made itself felt in the movements of the two important continents which it both separated and linked together. The Caucasus was a laboratory in which nature had been working on the largest scale, and magnificent results were given in its varied geological formation, &c. The beginning of the establishment of the Cossacks in the Caucasus dated some centuries back, and their numbers were systematically augmented by Peter the Great and his successors. After a reference to the various Tartar tribes, and to the Tcherkissis, whose habits were graphically described, other portions of the inhabitants of the Caucasus were similarly noticed. So far from Shamil being the chief of the Circassians, they looked upon his "levelling" system of government with suspicion and dislike; and it was only among the Tchetchess and Lesghins that Shamil had any power. The Caucasus possessed every diversity of soil; it was capable of producing indigo and cotton. The silk trade had received a stimulus by the failure of the supply in other quarters. During the Irish famine, 125,000 bushels of Indian corn were exported to this country. In the Caucasus, as elsewhere in the East, Swiss manufactures were gaining rapidly on those of England, a fact which Mr. Herries ascribed to the circumstance that hand-loom patterns and colours could be constantly varied without difficulty or expense, which, he said, was not the case with power-loom weaving. In the bazaars in Mingrelia, however, the average of British goods as against Swiss was generally as three to two. Steam had been introduced both on the Black and Caspian Seas and elsewhere.

On the Geography and Natural History of Western Equatorial Africa. *By* P. B. DU CHAILLU.

This singular region, explored by the author during the years 1856–7–8–9, lay within two degrees on either side of the equator, and extended for 400 miles into the interior. Having described its physical features, its partly swampy, partly mountainous character, and its dense forests, which ascend to the very tops of the mountains; its rivers, the Muni, the Moondah, and the Gaboon, all rising in the range of mountains known as Sierra del Crystal, 60 or 80 miles from the west; also the Nazareth, the Mexias, and the Fernand-vaz, the latter chiefly fed by the Ogobai, and this last fed by the Rembo Ngouyai and the Rembo Okanda; the traveller, reverting to the mountains, said, "Judging from my own examination, and from the most careful inquiries among the people of the far interior, I think there is good reason to believe that an important mountain-range divides the continent of Africa nearly along the line of the equator, starting from the west from the range which runs along the coast north and south, and ending in the east, probably in the country south of the mountains of Abyssinia, or perhaps terminating abruptly to the north of the lake Tanganyika of Captains Burton and Speke." To the existence of this range, and of the flat, wooded, damp country at its foot, he attributed the fact that Mahometanism had never in Africa spread south of the equator. The natural history of the country was next referred to at some length. With regard to the gorilla, he considered it probable that its range was coextensive with the dense jungle of the interior. He had no doubt that with the advance of civilization in that region this monster would disappear; and it was a great satisfaction to the scientific world and to himself to know that, whatever might happen, the world would have, from the pen of one of its most illustrious zootomists, Professor Owen, an imperishable record of the most wonderful anthropoid animal yet described.

On the People of Western Equatorial Africa. *By* P. B. Du Chaillu.

His travels extended from two degrees north to two degrees south of the equator. He doubted whether there is another district of the same size as that which he explored in Western Equatorial Africa, holding so many varieties of tribes, all thinking themselves separate nations and possessing different names, though many speak the same language or dialect. One of the great peculiarities of most of these tribes is that their villages are intermingled with each other. There are no landmarks assigned to each tribe; every village squats and settles where the people choose, and every now and then the traveller will be astonished to see a village belonging to a certain tribe far removed from it. This habit of selecting land wherever the people of a village like is owing to the vast extent of unoccupied territory. He found that the cannibals are the tallest and handsomest of these tribes; many were of athletic forms—in fact, magnificent savages; but he had found Fans near the equator, at the head-waters of the Gaboon River, who had not the fine appearance of these mountaineers. They even eat the dead. With the exception of these cannibals, the other tribes seem to be intermediate in stature, between the tall and slim. Yolof and other tribes of North Africa, and the small-sized men of the Congo and of the more southern tribes of that continent, according to the specimens he had seen, are small and ugly, but the Kaffirs are tall and handsome negroes. These equatorial people are well-proportioned, not stout, but built as if capable of enduring great fatigue. They may, as a whole, be called middle-sized men. Among the cannibals the females appeared in many instances smaller in proportion to the males. According to the commonly received notion, the negroes dwelling under the line, or near to it, ought to be darker than those removed from the line. This is a mistake. The countries he had visited do not possess what we should call black negroes, with the exception of the Ashira tribe, who are in contrast with the tribes surrounding them. He had come to the conclusion, from his observations, that the negroes who inhabit a damp and moist country, and especially mountainous countries, are less black, though they possess all the negro features, than those belonging to an open country, where a dry atmosphere is prevalent. In fact, the equatorial negroes are far from being as dark as the negroes he had seen living near the great desert in the Senegal country. Among the cannibals, but more especially among the Apingi, he had found persons looking almost like mulattoes. Albinos are rather common in the tribes he had visited. In this part of equatorial Africa the negroes inhabiting the sea-shore are a shade darker than those of the interior. The negroes of this part of equatorial Africa do not belong to the lowest type of the Western coast; they are superior to those of the Congo or more Southern-African tribes. The cannibals may be considered as among the best blacksmiths in Africa. They work iron in a most beautiful manner. They make knives, spears, axes, and hammers, many of which are good and beautifully shaped. The cannibal tribes are the only ones he had seen using the poisoned arrows. The tribes he visited south of the equator possess a loom, and weave the fibres of a species of palm into cloth of considerable fineness and tenacity. Among the people of the same tribe intelligence varies considerably. These negroes possess an imaginative mind, are astute speakers, sharp traders, great liars, possessing great power of dissimulation, and are far from being in many respects the stupid people they are believed to be. In making bargains they are as shrewd as any European. In everything that does not require mental labour and forethought they seemed to learn as fast as any among the intellectual races, to a certain point. When he had to rely on them for anything that required the exercise of memory or forethought, anything on which the power of reflection was required, then they failed; partly, perhaps, through laziness. Though often treacherous, they have noble qualities, are given to hospitality: food is never bought; the rich and the poor have food enough to satisfy their hunger. The women show great tenderness of heart, especially when one takes into account how harshly they are treated. Many times he had been under great obligations to them when sick for their kind care. They built houses either with the bark of trees or a species of wild bamboo: the houses are small, and there is no other opening than a door; sometimes, however, they possess two doors. With reference to the law of intermarriage, the author read a long extract from his published work on that subject. A universal belief existed in good and evil spirits, and in the power of charms, called Monda, made with a variety of objects. They also believed in the power of witchcraft and the significance of dreams. He had come to the determined conviction that, though these people lay offerings upon the graves of their friends, though they even sometimes shed the blood of slaves on the grave of a chief or that of a father of a family, though they fear the spirit of the recent dead, they have no definite idea as to the state of the soul after death. It is true they fear the spirit or ghost of the recently departed, and place furniture, dress, and food on their graves, and return from time to time with fresh supplies of food. The spirits of the victims slain at the graves, whether women or men, it is believed join that of him who has departed. During the season appointed for mourning, the deceased is remembered and feared; but when once his memory grows dim, fear gradually lessens, presents of food over the grave become more and more scarce, and the generation that comes afterwards, and who never saw the man, abstain from giving any present whatever, and take no concern about such spirit. The burial-ground exists only among a very few tribes; but among many, as soon as a person has died, the corpse is left under a tree, and the village is removed to a far distance. Ask the negro where is the spirit of his great grandfather: he says he does not know; it is gone. Ask him about the spirit of his father or brother, who died yesterday; then he is full of fear and terror; he believes it to be generally near the place where the body has been buried. There is, as he had mentioned above, a total lack of generalization. Thus some will believe that a certain man's soul, after he died, went into the body of a bird, beast, or gorilla; but ask them concerning the transmigration of souls in general, they will say they know nothing. They fear the spirit of the recently departed; they think of it as a vindictive thing which must be conciliated. All the tribes he had visited had faith in the power of existing spirits, generally called Obambou, or Oconcou, and the other Mbuiri; they have other names in various tribes which come near to these names; both appear to have power to do good or evil. They are not represented by idols, but in many villages have houses built for their occupation when tired of wandering, and food is offered to them. In some tribes they are believed to be married to two female spirits; they are said sometimes to walk in the street of the village and to speak to those they meet. They believe in idols, and each clan and head of a family possesses one. These idols are believed to have the power to keep the clan out of evil, and to be able to foretell events. The people, the author continued, are totally ignorant of God or a Supreme Being. Witchcraft was believed in; polygamy was very prevalent; and slavery an institution of the land. Slaves were the money of the country, the standard of valuation. Many of these African tribes are fast disappearing; their languages or dialects will disappear with them.

On the Antiquity of Man, from the Evidence of Language. *By* JOHN CRAWFURD, *F.R.S.*

The periods usually assigned for man's first appearance on earth necessarily dates only from the time when he had already attained such an amount of civilization as to enable him to frame some kind of record of his own career, and take no account of the many ages which must have passed away before he could have attained that power. Among the many facts which attested the high antiquity of man was the formation of language. Language was not innate, but adventitious—a mere acquirement, having its origin in the superiority of the human understanding. The prodigious number of languages which existed was one proof that language was not innate,—some with a very narrow range of articulate sounds, others with a very wide one; some confined to single syllables, while others had many; some being very simple and others of a very complex structure, thus implying that each tongue was a separate and distinct creation, or that each horde formed its own independent tongue. A whole nation might lose its original tongue, and in its stead adopt any foreign one. The language which was the vernacular one of the Jews 3000 years ago had ceased to be so above 2000 years ago, and the descendants of those who spoke it were now speaking an infinity of foreign tongues—sometimes European and sometimes Asiatic. Languages derived from a single tongue of Italy had superseded the many native languages which were once spoken in Spain, in France, and in Italy itself. A language of German origin had nearly displaced not only all the native languages of Britain and Ireland, but the numerous ones of a large portion of America. Some eight millions of negroes were planted in the New World, whose forefathers spoke many African tongues, which tongues had nearly disappeared, having been supplanted by idioms derived from the German and Latin languages. It necessarily followed that man, when he first appeared upon earth, was destitute of language. Each separate tribe formed its own language; and there could be no doubt that in each case the framers were arrant savages, which was proved by the fact that the rudest tribes ever discovered had already completed the task of forming a perfect language. The first rudiments of language must have consisted of a few articulate sounds, in the attempts made by the speechless but social savages to make their wants and wishes known to each other; and from those first efforts to the time in which language had attained the completeness which it was found to have reached among the rudest tribes ever known to us, countless ages must be presumed to have elapsed. The Egyptians must have attained a large measure of civilization before they had invented symbolic or phonetic printing, and yet these were found in the most ancient of their monuments. Dr. Adam Smith divided all languages into two classes, complex and simple; the complex being considered the primary form of all languages, and the simple but derivations, the products of the intermixture of nations speaking different tongues, and striving to make themselves intelligible to each other. In this case, one tongue would be adopted; and, to make it easy of mutual use, it would be stripped of its inflections, easy prepositions, &c., being substituted for them. It was certain, however, that the principle could not be of universal or even general application, and that there were many languages of simple structure just as primitive as those of complex formation. One language might receive even a considerable infusion of another without undergoing any change of structure. There were cases in which, from several causes, even the conquest of one people by another, and the long possession of the conquered territory, might produce no change in the structure of language. In some cases the invaders might be so overwhelming as to be able to supplant the language of the conquered by their own, without the latter undergoing any change. In this way the Saxons substituted their own language for the native idioms of Britain, that language not losing its inflections until it afterwards came to be intermixed with the speech of a new set of conquerors. The substitution of the languages of Europe for those of the New World was a case of the same description—even a stronger one. It was quite certain, however, that many languages existed which never could have been formed by inflections. It appeared that the structural character which languages originally assumed would in a great measure depend on the whim or fancy of the first rude founders. No doubt there were facts in reference both to pronunciation and structure very difficult to account for, and which might possibly have some relation to physical differences of races. No monosyllabic language, whether in the Old or New World, seemed ever to have existed west of the nations whom we called Hindu-Chinese. Consonants, and especially gutturals and other rough sounds, abounded in the languages of North Europe. The structure of the ancient languages of Europe, and perhaps of Central Asia, appeared to have been formed by inflections, while the Malayan and Polynesian tongues were invariably of very simple structure. The American tongues, even the language of the Esquimaux, were formed by agglutination—the combining in one word an aggregation of several words—often to the formation of a word comprising the meaning of an entire sentence. Adam Smith supposed (and he, Mr. Crawfurd, thought justly), that the first attempts to form language would consist in giving names to familiar objects; that was, in forming nouns substantive. Words expressing quality would naturally be of later invention. Verbs, or words expressing affirmation, must (according to the writer he had quoted) have been nearly coeval with nouns themselves, since without them nothing could be affirmed; and pronouns were not likely to have existed at all in the earlier period of language. The same author said that number, considered in general, without relation to any particular set of objects numbered, was one of the most abstract and metaphysical ideas which the mind of man was capable of forming, and consequently was not an idea which "would readily occur to rude mortals who were just beginning to form a language." The truth of this view was corroborated by our observation of rude languages, in which the process seemed to be going on. Among the Australian tribes "two," or a pair, made the extent of their numerals. Some other tribes had advanced to count as far as "five" and "ten." The Malayan nation had native numerals extending to a thousand, above which they borrowed from the Sanscrit. The rude and imperfect numerals of some tribes would seem to have been superseded by the more comprehensive ones of more advanced nations, a remarkable example of which was the general prevalence of the Malayan numerals among all the nations of the Malayan and Philippine Archipelagos, among the tribes, whether fair or negro, of the islands of the Pacific, and even among the negroes of Madagascar. The Roman numerals had been adopted, to the supercession of their own, by the Celtic nations. The two hands and the ten fingers seemed to have been the main aids to the formation of the abstractions which Adam Smith considered so subtle. This would account for the numeral scale being sometimes found binary, sometimes quinary, but generally decimal. However great the difficulties of constructing languages, there was no doubt they were conquered by mere savages. Language was even brought to perfection as to structure, and for the expression of ordinary ideas, by men who were but barbarians. The poems of Homer, composed before the invention of letters, were as perfect Greek as any that were ever after written. The Sanscrit language, in all its complexity and perfection of structure, was spoken and written at least three thousand years ago by men who, compared with their posterity, were completely barbarian. The Esquimaux had a language of great complexity and structure. Languages, then, were formed everywhere by rude savages, and time alone seemed to have been sufficient to enable them to elaborate a system perfect for its purpose with every race of man. The vocabulary of the rudest tongue probably embraced not fewer than 10,000 words, every one of which had to be invented. These words, in order to form a coherent system, had often to undergo modifications of form, and some of them, besides their literal meaning, had to receive metaphorical ones. What ages, then, must not have elapsed from the first attempts to assign names to a few familiar objects, to that in which language had attained the completion at which it had arrived, as we find it even among cannibals! Between the completion in question and the discovery of the art of writing, made only here and there, under very favourable conditions as to race and locality, how many additional ages must not have transpired! That discovery implied an advanced civilization, the fruit of very long time. If we considered the introduction of the art of writing among the Jews, for example, to have been coeval with the Pentateuch, this alone would carry us back in the history of language for near 3500 years, according to the usual computation. But at the time at which the Pentateuch was written, the contemporary Egyptians were a far more civilized people than the Jews, and had been long in possession of the art of writing. He thought the conclusion was inevitable that the birth of man was of vast antiquity. He came into the world without language, and in every case had to achieve the arduous and tedious task of constructing speech, which, in the rudest form in which it was now found, it must have taken many thousands of years to accomplish.

On the Antiquity of the Aryan Languages. By R. Cull.

On the Ethnology of Finnmark, in Norway. By L. Daa, *of Christiania.*

The district of Finnmark was situated at the extreme north of Norway and Sweden. Its population was very scanty, but was also very diversified; there were three great divisions:—the aboriginal Laps; the Norwegians, being immigrants from Norway; and the Fins, from Finland in Russia. The former were chiefly nomade, and the others were almost exclusively fishermen, living on the coast and banks of the rivers. In 1855 the population of Finnmark proper was 15,385 souls, and consisted of 5300 Norwegians, 1425 Nomades, 5786 settled Laps, and 2305 Finlanders. Each of the three nationalities spoke a different tongue. Mr. Freiss, of Norway, had lectured upon the Laps and Fins, and from inquiries conducted under his superintendence a map was constructed, and from this and some statistics which had been given, the author drew conclusions to the effect that the Norwegians and Fins were the more civilized, and that while the Laps were learning their languages, the Norwegians and Fins knew nothing of the language of the Laps, and that the connexion between the Laps and the Fins was more intimate than between the Norwegians and the Laps.

New Commercial Route to China. *By* Henry Duckworth, *F.L.S., F.G.S., F.R.G.S.*

The object of this communication was to give a summary of a project recently placed before the Government and commercial community of this country by Captain Richard Sprye and the writer of this paper.

In his prefatory remarks the author observed that our most recent acquisitions of territory in Burmah had brought us within 250 miles of the Chinese frontier.

There being no direct communication between the two countries, it became a most important question whether it would be possible and profitable to establish one.

The seven most western and inland provinces of China proper are situated between about 22° and 42° north latitude, and lie far west of the extreme point to which Lord Elgin proceeded up the Yang-tze-kiang.

The chief natural productions of Yun-nan (area, 107,969 square miles; population, 8 millions) are rice, silk, musk, various kinds of drugs, and tea. Gold, copper, lead, cinnabar, and orpiment are abundant; indeed, Yun-nan excels all the other provinces in its mineral wealth.

Kwangsee (area, 78,250 square miles; population, 10½ millions) produces abundance of rice, cassia, and valuable furniture-woods. Gold, silver, and quicksilver are the principal metals.

Kweichoo (area, 64,554 square miles; population, 7½ millions) yields wheat, rice, musk, tobacco, cassia, and precious timber. Lead, copper, iron, and quicksilver are found in its mountains.

Hoonan (area, 73,000 square miles; population, 33 millions), one of the richest provinces in the empire, produces immense quantities of grain, principally rice. Its teas are said to be remarkably fine. Iron, lead, and coal are abundant; and the mountains produce pine, cassia, and various other kinds of timber.

Sze-chuen (area, 166,800 square miles; population, 30½ millions) is the largest and, according to Abbé Huc, the finest province in China. Its fertility is such that, it is said, the produce of a single harvest cannot be consumed in it in ten years. Its principal productions, besides grain, are indigo and various tinctorial plants, fine teas, silk, sugar, grass-cloth fibre (*Bœhmeria nivea*), and many kinds of valuable drugs.

Shensee (population, 14½ millions) is too cold for rice and silk; wheat and millet supply their place. Rhubarb, musk, wax, red-lead, coal, and nephrite are the principal articles of exportation.

Kansu (area, with the last, 154,000 square miles; population, 22 millions) produces wheat, barley, millet, and tobacco of very superior quality. A large traffic is carried on between this province and Tartary in hides and coarse woollen cloths.

The means of reaching these seven rich and densely-populated provinces from the Bay of Bengal is very simple.

Taking Rangoon as the starting-point, it is proposed to connect that port with an emporium in the north-east corner of Pegu, *i.e.*, under the magnificent Karen Hills. From this emporium, which would be almost equidistant from Rangoon and the Chinese frontier, the line of communication would pass through Burman-shan territory to Esmok (or Sze-maou), a border-town of Yun-nan, and a point at which several caravan-roads converge directly from various parts of the province, and indirectly from the whole of the western half of the empire.

In order to take-in chief towns and our military stations, the line would proceed thus:—1st stage, Rangoon to the ancient city of Pegu, the intervening country being almost level; 2nd stage, from Pegu, over flat land across the Sittang to Shoe-gyen; 3rd, Shoe-gyen, up the left bank of the Sittang and Kyoukkee rivers to Baukatah, a distance of 35 miles; 4th, from Baukatah up the left bank of that river and its tributary, the Peemabhu, to Thayet-peen-keentat, also 35 miles; 5th, across the watershed between the Sittang and Youngsalen to the Kweestookee branch of the Thaiboot river, and down their right or left banks to the Youngsalen, down and across which to Tzeekameedac; 6th, thence over the watershed between the Youngsalen and the Salween to our frontier-line under the Karen Hills, where we are within reach of all the Chinese and Shan caravans which traverse the country north-west of that point.

Another most important feature in the project is the establishment of an electro-telegraphic communication along the whole route. The line, once brought to Esmok, could be easily carried across country to the Pearl river, and down the lower valley of that stream to Canton and Hongkong, and thence, taking in the principal towns along the coast (Amoy, Foochow, Ningpo, and Shanghai), to Pekin.

In like manner, by extending the communication to Niew-chiang, and down the Corea, the open ports of Japan might be brought to the very door of Rangoon, which already possesses telegraphic connexion with Calcutta.

On the Capabilities for Settlement of the Central Parts of British North America. *By* JAMES HECTOR, *M.D., F.G.S., F.R.G.S.*

The region noticed by the author extended from Lake Superior to the Pacific Ocean, lying immediately north of the boundary-line of the United States, and was drained principally by the river Saskatchawan. A considerable amount of agitation had been employed in Canada and at home, in order to have this country thrown open for settlement; the whole, with the exception of that portion which fell within British Columbia, being under the direct control of the Hudson's Bay Company for the purposes of a für-trading monopoly. It had been placed beyond doubt, principally through the labours of several government expeditions, to one of which he was attached, that there existed within these territories extensive areas, with good and varied soil, adapted for agricultural colonization, but which, from their geographical position, were necessarily subject to all the advantages and defects of a temperate continental climate. The winter was long and severe, the spring short and uncertain, and the summer tended to scorch the vegetation. The winter, however, was not more severe than that which was experienced in Canada and elsewhere. Many crops which were readily raised in Canada would not meet with equal success in the Saskatchawan; but all common cereals and green crops had been grown successfully. The depth of the snow was never excessive, while in the richest tracts the natural pasture was so abundant that horses and cattle might be left to obtain their own food during the greater part of the winter; and there was no doubt that sheep might be reared, were it not for the immense packs of wolves which infested the country. These remarks applied more especially to the "Fertile Belt." The Saskatchawan country offered a most desirable field to the settler who was deficient in capital, and who had no desires beyond the easy life and moderate gains of simple agricultural occupations. It was only the difficulty of access to it that prevented its immediate occupation. One route from Hudson's Bay, by a broken land and water carriage, was now almost abandoned. A second route was from Lake Superior to Lake Winnipeg, which had the same disadvantages. The third line of ingress, undoubtedly the natural one, passed through American territory, up the valley of the Mississippi river to the Red River settlement, by way of St. Paul's, Crow Wing, and across the low watershed which there divided the waters of the Mississippi from those flowing to Hudson's Bay. The progress of the adjoining American settlements was then noticed. In the rugged country which lay between the Rocky Mountains and the Pacific coast, no doubt all the valleys were filled with rich auriferous deposits; diggings were constantly being discovered in fresh localities. The formation of a line of railway through British Columbia would involve great difficulties. Throughout the Saskatchawan country there were deposits of coal of considerable value, though not to be compared with that which was common in England. Coal of somewhat better quality also occurred at Vancouver's Island; and that colony was a valuable link in a chain of communication with China and the East Indies, by way of a line of route across the North American continent.

On the Relations of the Population in Ireland, as shown by the Statistics of Religious Belief. By the Rev. A. Hume, *LL.D., D.C.L.*

This paper was in continuation of an analysis which the writer had made of part of the Ecclesiastical Census of Ireland for 1834. It referred to the two counties of Down and Antrim; and the results were published, with curious ethnological maps in illustration of them. Of 135 benefices, some one class of the people rose to more than 50 per cent. in 117 instances; viz., Presbyterians in 70, Roman Catholics in 36, and Established Church in 11.

Looking only to the geographical counties (except in the cases of Dublin, Belfast, and Carrickfergus), and omitting decimals, every 100 people are divided as follows:—Roman Catholics (or Celts) 78, Churchmen (or Normans and English Saxons) 12, Presbyterians (or Scottish Saxons) 9, minor sects of Protestants (mixed) 1.

The Presbyterians are most concentrated, 94 per cent. of their number being in Ulster, 3 in Leinster, 2 in Munster, and 1 in Connaught; indeed, 60 per cent. are situated in Down and Antrim, including Belfast; and if we add Londonderry and Tyrone, 81 per cent., or more than four-fifths, are in those four shires. The Established Church has 58 per cent. of its members in Ulster, 25 in Leinster, 11 in Munster, and 6 in Connaught. It is therefore better distributed. The Roman Catholics are best distributed; viz., Munster, 31; Leinster, 28; Ulster, 22; and Connaught, 19. The great towns, being recruited from the rural population round them, will in time become more Celtic or Roman Catholic, just as Belfast, which was originally English, has become Scotticised by the influx of neighbouring Presbyterians.

The three classes of population attain their highest and lowest relative proportions at different points of the country; and in general the explanation of the facts is simple. The Roman Catholics reach 97·71 in Clare, and shade off in Mayo, Kerry, Roscommon, Galway, &c., not falling below 90 per cent. in sixteen counties. The Established Church is highest in Fermanagh, where it rises to 39 per cent. of the gross population; then in Armagh, 31; softening down in Belfast, Tyrone, Dublin city, and Down county, in none of which do its numbers fall below 20 per cent. Presbyterianism reaches its maximum at Carrickfergus, 59; descending by Antrim, 53; Down, 45; Belfast, 36; and Londonderry, 35; but in twenty-two counties, embracing nearly the whole of three provinces, it does not reach 1 per cent. of the gross population.

In general the numbers representing Churchmen (or English Saxons) and Roman Catholics (or Celts) are the complements of each other, the descending figures in the one case nearly corresponding with the ascending ones in the other. But five or six of the lowest Roman Catholic numbers are baanced, not by Churchmen, but by Presbyterians, as given in the previous paragraph; all the examples lying in the three shires of Down, Antrim, and Londonderry, where the Scottish element is strongest.

Since 1834 the Presbyterian element has diffused itself, though still greatly concentrated. In general it is represented at the new points in the south and west by a preponderance of males; while the instances in which Roman Catholic males exceed the females are remarkably few. Persons of the former class find new homes by the demands of trade and agriculture; persons of the latter class serve to swell the tide of emigration which flows westward, the males being usually the pioneers. These are only a few of the inferences suggested by the figures already given to the public as anticipatory of the general census.

A Letter from Sir Hercules Robinson, *Governor of Hongkong, relating to the Journey of* Major Sarel, Capt. Blakiston, Dr. Barton, *and another, who are endeavouring to pass from China to the North of India. By* Sir R. I. Murchison, *D.C.L., F.R.S.*

These travellers ascended the Yang-tse-kiang to 800 miles above Hang-kow, found much coal with limestones and conglomerates in the cliffs forming the banks of that mighty stream, had travelled in their European dresses, and had encountered no great difficulty until they were near the capital of the great province of Sze-chuen (population 15 millions), and in which French Jesuit missionaries have long been settled. The country towards the frontier of Tartary was in such a disturbed state, and for the most part overrun by multitudes of rebels (not the Tae-pings), that the travellers, being unsupported, were obliged to return by the river to Hang-kow and thence to Shanghai.

A Letter from the Colonial Office, on the Exploration of N.W. Australia, under Mr. Gregory.

Sir R. I. Murchison communicated the substance of a letter he had received from his Grace the Duke of Newcastle (Colonial Office), assenting to the recommendations of the Royal Geographical Society, that a sum of money exceeding that which was originally contemplated would be guaranteed to Mr. Frank Gregory to complete his explorations of North-Western Australia. That traveller was to go northwards, turn the north-west corner of the continent, and proceed as far as possible eastwards towards Cambridge Gulf. The colonists of Western Australia who first recommended this exploration had a more limited object in view, wishing merely to extend their feeding-grounds. The proposed exploration was one of the utmost national importance at the present moment; for the land thus explored was where cotton grew as a native plant, and in abundance. It was partly with a view to ascertain some of the cotton-growing capabilities of this neighbourhood that the exploration was about to be undertaken. The feat of M'Douall Stuart in crossing the continent from South Australia to the northern watershed was one which the Royal Geographical Society had recompensed by awarding to him their gold medal.

Remarks on the Proposal to form a Ship Canal between East and West Loch Tarbert, Argyllshire. By John Ramsay.

The length of the proposed canal from high-water mark on the one side to high-water mark on the other would be 1600 yards. On the voyage between the Clyde and West Highlands the distance saved would be fully sixty miles. Eighty years ago the difficulties and dangers of the navigation had led to the consideration of this proposal, and it was again brought forward in 1846, when the probable expense was estimated at £101,267 18*s*. 9*d*.

On the Direct Overland Telegraph from Constantinople to Kurrachee. By Colonel Sir Henry C. Rawlinson, *K.C.B., D.C.L., F.R.S.*

In 1858 the Turkish Government undertook to execute, at its own expense, a line of telegraph from Constantinople to Bussorah, which would form an integral portion of the great line connecting India with Europe. It was foreseen that the line would be convenient both for the requirements of the Turkish trade and the purposes of the Turkish Government, and would thus benefit the empire; but the money return for the outlay was to be sought in the tariff established for British messages transmitted along the line towards India. The British Government engaged, as soon as there was a fair prospect of the completion of the Turkish undertaking, to carry on the communication from Bussorah to India at its own expense. Some of the officers originally engaged in the undertaking had retired; but three of Lieut. Holdsworth's *employés*, Mr. Carthew and the brothers M'Cullum, remained in the country, and, mainly owing to their zeal and skill, the line was now in a working and efficient state the whole way from Constantinople to Bagdad. The Porte had declined to accede to a proposition that Her Majesty's Government should incur half the expenses of the improvements, but had formally engaged to carry out all Col. Kemball's recommendations for giving greater efficiency to the line at his own expense. A submarine cable from Pera across the Bosphorus having been frequently damaged by the anchors of vessels, it was proposed to suspend a wire from the European to the Asiatic side at the narrowest part of the strait—a distance of not more than 1000 yards. Precautions had been taken as security against interruption from the Arabs, Kurds, &c., by the line of telegraph being taken from Marden along the chain of the Masius, where there are located a great body of Jacobite Christians. Col. Kemball reported favourably of the progress of efforts to conciliate the Arab chiefs living near the outer ranges of the Kurdish mountains. The telegraph consisted of two distinct wires, one of which was reserved for the exclusive use of the British Government; and a convention was about to be signed with the Turkish Government for the regulation of the respective shares of the expense to be incurred in keeping the line in working order, for fixing the tariff for the transmission of messages, &c. With reference to the Persian section of the line, attention was being more immediately directed to a continuation of the land-line from Bagdad, through Persia, towards India. Political and physical arguments showed the desirability of taking a northward line, and the author believed that it had been decided to continue the line, in the first instance, directly from Bagdad to Teheran, thence to Khanikeen and Kermanshah. From the latter place it would continue to follow the great high road from Babylon eastward. At Teheran the line would join another system of telegraphs which had been organized in Persia itself. From Bagdad it was proposed to continue the line to Bunder Abbas; and it was almost certain that the Shah would enter cordially into the scheme. The Commissioner in Scinde, the agent for the Government of India, and the Imaum of Muscat had reported as favourably as could be wished. They were working in what he believed, in the present state of oceanic telegraphy, to be the only practicable direction.

On the Spitzbergen Current, and Active and Extinct Glaciers in South Greenland. By Colonel SHAFFNER.

In June 1777, ten whaling vessels were beset in the ice about lat. 76° north, between Spitzbergen and Jan Mayen. They endeavoured in vain to escape, were carried by the ice in a south-western direction between Iceland and Greenland, and by degrees the vessels were all lost; only 116 of the 450 men who composed the crews escaping, they having reached the South-Greenland coast. Little was known of the loss of these vessels; but it might be supposed that the floe ice was not compact, and that they were chafed until their hulls were worn, so as to permit the water to enter them. On the 22nd of June, 1827, Captain Parry started on a boat expedition from Spitzbergen towards the North Pole—one of the most hazardous efforts known in Arctic annals; but he was obliged to put back on the 24th of the following month, and return to his ship at Spitzbergen, the drift or current having carried him 14 miles to the southward in the last two days of the journey. South of Spitzbergen and Jan Mayen the ice sometimes spread and came south upon North Iceland, the gales north of Iceland and south of Spitzbergen spreading the ice in detached pieces or small bergs eastward, from 100 to 200 miles from the current track, which runs southward along the Greenland coast. Directly west of Iceland, the floe ice had seldom been seen from the highest mountains. South of Iceland, the ice-floe was in the direction of Cape Farewell. Timber was often found drifting near the east and west coasts of Greenland. The width of the Greenland current did not, in his (Col. Shaffner's) opinion, exceed 50 miles; it carried with it floe ice and berg ice. It was not known that much of the floe ice came from the icy seas north of Russia. The year 1860 was remarkable for the great quantity of ice brought by the Greenland current, and, added to that brought south by the Baffin's Bay and other currents of Davis's Strait, produced the unusual dangers experienced in navigation from America to Europe in 1861. More ice had been seen in the usual track of the steamers during this year than at any previous period. This was to be expected after the reports from the 'Bulldog' and 'Fox' expeditions of 1860. Captains of vessels from Greenland reported that there had been but little ice in the Greenland current this year; and it might be expected that navigation between America and Europe would be but little hindered by the ice in 1862. When north-east winds blew, the coast was free from ice; a west wind drove the ice upon the coast. It might be safe to estimate the velocity of the Greenland current at 10 nautical miles per hour from north of Spitzbergen and Cape Farewell, and then northward to about latitude 64° north, where it began to spread and join with the northern or Baffin's Bay current. The length of this current being about 1600 nautical miles, and supposing its width to be 50 miles during four months of the year, they might estimate the decay of ice from 75,000 to 80,000 square miles, within the track of the Greenland current. On the subject of glaciers, the Colonel expressed his opinion that the "Igalikko" was once an ice-fiord,—that the glacier extended where water was now seen, the water reaching even more into the interior than the edge of the present glacier—the moving of the ice having ground up the rocks, and the earth and the small particles gradually filling up the fiord. The supposed ice-area of Greenland being about 400,000 square miles, such an area ought, if all of it were ice, to give off more upon the known coast than was seen. It was reasonable to doubt the existence of such an extent of ice.

The English Gipsies and their Dialect. *By* BATH C. SMART.

The author of this paper was careful to explain in the outset that he did not profess to deal with comprehensive questions relating to the Gipsy race as a *whole*, but that his observations were limited to his own personal experience among the English Gipsies. He began with a short description of the chief physical and psychological characteristics of the Romany people as they are now to be met with in England. In addition to their swarthy skin and black hair and eyes, he remarked the prevalence among them of a well-marked aquiline nose, and the obliquity of the orbital arches, which slant upwards to the glabella or root of the nose, combining together into one common arch, instead of appearing to be segments of two separate circles, these several features forming a *tout ensemble* having an oriental cast strikingly different from the Anglo-Saxon physiognomy, or that of any other British race. The latter and by far the larger portion of the paper was devoted to the linguistic peculiarities of the English Gipsies. His remarks under this head were based on a vocabulary, which accompanied the paper, of upwards of 800 words collected by himself during actual intercourse with members of various Gipsy families. These words had all been minutely compared with Grellmann's and Borrow's German and Spanish Gipsy Dialects, and their homologies traced wherever it was possible. The following is a *brief* sketch of the remarks made on the composition of words and of the various parts of speech and their inflections:—

A peculiarity of the Gipsy language wherever spoken is the number of words terminating in *engro* or *mengro*, *escro* or *mescro*, but the English dialect seems especially rich in these compounds; *e. g.*,

Bockoromengro	A shepherd.	From Bokoro (sheep).
Boshomengro	A fiddle.	From Bosh (to fiddle).
Cooromengro	A soldier.	From Coor (to fight).
Massengry	A butcher.	From Mass (meat).
Sastermescro	A blacksmith.	From Saster (iron).
Poggeromesty............	A hammer.	From Pogger (to break).

But perhaps the most characteristic termination of all is *ben*, or *pen*, added to adjectives and verbs to form substantives. This affix is also of frequent occurrence in Hindustani:—

Tatchipen	Truth.	From Tatcho (right).
Hobben (for Holben)......	Victuals.	From Hol (to eat).
Naffilopen	Sickness.	From Naffilo (ill).

The Gipsies have manufactured and adopted a class of words, generally appellatives, which are essentially of the nature of puns. They consist of words in which a fancied resemblance of sound has suggested their translation into Romanes; *e. g.*,

Lalopeero (red foot)	Redford.
Milesto-gav (donkey-town)	Doncaster.

Interchanges of certain letters frequently occur in Gipsy words, but always according to rules; and this must be borne in mind in tracing their derivations. Interchanges take place between the following letters—K and H, K and T, G and D, F and S, &c., and the liquids are very often confounded.

GRAMMAR.

Masculine nouns generally end in a consonant or *o*.

Feminine nouns nearly always end in *i* or *y*; *e. g.*,

Gairo	Man.	Gairy	Woman.
Krallis	King.	Krallissy	Queen.

The genitive case singular is formed by adding *esto* or *esko*; *e. g.*,

	Genitive.
Giv (corn)	Givesto or Givesko.
Ven (winter)	Venesko or Venesto.

The plural is formed by adding *yor* or *or* to the singular:—

Skammin (chair)	Skamminyor.
Shock (cabbage)	Shockyor.
Pal (brother)	Palor.

The Gipsies as often use the English plural in *s*:—

Joovvel (woman)	Joovvels.
Pen (sister)	Pens.

Adjectives end in *o* or *y*, agreeing in this respect with masculine or feminine nouns; *e. g.*,

Mas.	*Fem.*
Rinkenno (pretty)	Rinkenny.
Chicklo (dirty)	Chickly.

The comparative degree is formed by adding *dair* or *dairo*; but no peculiar form is met with for the superlative:—

Door (far)	Doordair (further).

The comparative degree is sometimes formed irregularly:—

Cooshko (good)	Fetterdairo (better).

The English Gipsies still use a great many of their peculiar pronouns; *e. g.* Mandy (I), too (thou), yov (he), yoi (she), yaun (they), adoovvo (that), acoovoo (this), &c. The second and third personal pronouns in the English dialect are thus declined, viz.—

	Thou.	*He.*	*She.*
N.	Too,	Yov,	Yoi.
G. D.	Tooty,	Lesty,	Latty.
Ac.	Tooty or Toot,	Les,	
Ab.	Tooty,	Lesty,	Latty.

According to Grellmann, the German and Hungarian Gipsies have a peculiar conjugation of their own. The Gitanos of Spain assimilate their verbs to the Spanish conjugation. In this country the Gipsy dialect still exhibits remnants of its ancient mode of conjugating the verb, although it generally conforms to the English method in preference. Thus, the termination *ella* often appears in the third person singular of the present tense, and the past participle ends in *o* or *do*:—

Nasher (to lose) .. Nasherella (he loses) .. Nasherdo (lost).

Impersonal verbs always end in *ella* in the present tense; *e. g.*,

Brishinella (it rains) .... Yivyella (it snows).

A special form for the perfect is met with in some verbs; *e. g.*,

Jal (to go).... Jas (he or she went). Lel (to take).... Las (took).

Parts of the verb *to be* have been retained in common phrases, such as "Choom *see* aprey" = the moon *is* up, "Sar *shan*?" = how *are* you?

The Gipsies have a number of prepositions in common use; *e. g.*

Engl. Gipsy prepositions.	Hind. prepositions.
Agal	Age.
Adrey	Andar.
Aprey	Upar.
Talay	Tale.
Pawdel	Par.

On the syntax of the English Gipsy language very little was said; with but few exceptions, the sentences are arranged strictly in accordance with the English idiom.

On the Geographical Science of Arctic Explorations, and the advantage of continuing it. By Captain W. P. Snow.

Remarks on a Proposed Railway across the Malay Peninsula. By H. Wise.

It appeared that this railway would save a distance of about 700 miles, by connecting the Bay of Bengal and Indian Ocean with the Gulf of Siam and China and Japan Seas, and precluding the necessity of pursuing the circuitous and precarious navigation of the Straits of Malacca. The government of Siam had sanctioned the construction of the railway, for the praiseworthy reason that it was connected with the advancement of civilization. The length of the railway would not exceed forty-five miles, and the transit of mails and passengers overland from the Bay of Bengal to the Gulf of Siam, or *vice versâ*, would be accomplished in two hours. The present passage was made by steam-vessels in four or five days, but was seldom performed by sailing vessels in less than three weeks. The experience of Major Tremenheere, with respect to the proposed undertaking, showed that no great physical difficulties would have to be overcome in the construction of this line. The line would greatly facilitate the extension of the telegraph to China, by affording protection to the stations on the line. The cable from Rangoon, along Cochin China, to Hongkong would be liable to far less casualties than that by the Straits route. The district through which the line would pass contained coal, tin-ore, and valuable natural productions. In the neighbourhood was an abundance of natural woods. The entire area of the Malay Peninsula was about 83,000 square miles. The importance of this railway to British policy and progress in the East was incalculable.

Some Account of the Romans in Britain. By Dr. R. Wollaston.

STATISTICAL SCIENCE.

Address of William Newmarch, *F.R.S., President of the Section.*

He said there was some danger at this time that undue importance should be attached to what had been achieved in physical discovery. Enormous as had been our achievements—beholding, as they did, the prominent effects produced by railways, tubular bridges, ocean steamers, telegraphs, and rifled cannon,—there was some danger—and it was not a small one—lest we should attach excessive and undue importance to the obligations which society owed to these achievements and those discoveries, great as they were. A glance at the history of the last thirty years would show that there had been in operation economical forces, the effects of which were hardly of less importance. Sound doctrines had been applied to foreign and inland trade, taxation, education, sanitary science, prevention of crime, and the poor-laws. Economical science had ceased to be hypothetical, and had become experimental. This, the prominent fact in the history of the last thirty years, was due to the spirit of close scrutiny which had been carried into everything, including history, archæology, literature, and politics. It had been mentioned as a reproach to economical science, that it was not purely a science, but partook largely of the nature of an art. He must confess that this was scarcely a reproach; and the remark arose from a hasty view of the real difference between science and art. Science was really a collection of general principles; but all sciences were more or less arts. Astronomy, for example, led to the production of nautical almanacs; and physiology to hospitals, sanitary laws, and precautions against fire. Economic science must be essentially an art, inasmuch as its smallest problems involved human interests, affections, and passions; and the advances which had been made of late years arose from regarding it both as a science and an art. There was a great want of an accurate and convenient term for social science, which would include morality and religion, education, jurisprudence, municipal law, sanitary science, political economy, the fine arts, and the art of government. The Social Science Association had six sections; namely, jurisprudence and amendment of the law, education, punishment and reformation, public health, social economy, and international laws. It was probable that social science would soon imply, technically, political economy, jurisprudence, sanitary science, education, and statistics. He had mentioned statistics; but statistics was not properly a science, like dynamics and chemistry. Statistics had no body of doctrine, or of general laws, of its own. Its generalizations were of the second order. There were five main divisions, namely, vital statistics, criminal statistics, economical statistics, trade statistics, and taxation statistics. In all these, ultimate units were being gradually established. The annual death-rate was almost as important as Dalton's law of definite proportions. It had been established that the death-rate in a community of human beings inhabiting a country like our own ought not to exceed 17 in 1000, and taking their stand upon this, they were able to say that where the annual death-rate greatly exceeded that figure, there was something wrong. The rate of infant mortality was almost the best test of civilization. From the plan suggested by the Statistical Congress of last year, they should gradually be able to ascertain what was the real condition, and what was the effect, of the social relations pervading different parts of the world. The application of the experimental method pursued during the last thirty years had led to a large modification of the early and economic science in reference to free colonization, legal interference with labour, currency prices, the nature and operation of rent, and the effects of a large increase of metallic money. As to legal interference with labour, there was no part of political economy apparently so clear as that which taught that capitalists and labourers should be left to make their own bargain. Prior to Adam Smith and Ricardo, nearly all such interference by law and custom had been mischievous; and, therefore, experience seemed to be on the side of *laissez-faire*, and against guilds, syndics, and government officers. This was true so long as the labourers were of the adult class, working singly or in small numbers or in families. But it ceased to be true when manufacturers congregated workpeople in large masses, and largely employed women and children, who were only partially free agents. Capitalists said that the limiting the hours of labour would mischievously and fatally discourage capital; and so it would, in the abstract. But there were these qualifying conditions—that capital, depending for its return upon the order and energy of large masses of persons, must take especial care of the physical and moral condition of such persons; and that the efficiency of exertion, even with machinery, did not mean unlimited hours of labour, but skilled efforts during the best-selected parts of the day. The experiment had fully answered; and the orderly, educated, and contented labourers of Lancashire were security against foreign competition, and a guarantee of peace. Economic science dealt with six principal classes of questions, namely, the nature of wealth, the exchange of commodities, taxation and finance, currency and banks, wages and division of employment, and interference by the State. The last three only were still in dispute. Formerly with regard to these the *laissez-faire* principle seemed to be the general rule; but as society became more complex, it seemed to be clear that the State must in many cases protect individuals. It could not be denied that at present the tendency of civilization was to deal with rights in masses. The conclusion of the whole matter seemed to be, that as the result of the last thirty years, full as that period had been of scientific achievements, they might justly claim for the services rendered by economic science and statistical inquiry a place in the front rank; that they had now arrived at a kind of intermediate point, at which, after long debate, many controversies were finally settled, and from which they might see their way to a higher summit; and that the least doubtful result of their experience had been the discovery that the most solid progress was made by guiding themselves in the main by close observation of facts, and by employing speculative and hypothetical reasoning under the most cautious conditions. But there was a larger moral beyond these results. The last thirty years had been an age of renaissance, because they had found out that human life had higher ends than employment in incessant labour or devotion to excessive gain; that to accomplish these higher ends they must free themselves bodily and wholly of artificial and false supports, and contest with no mimic earnestness for the honour of the first place among modern civilized States. He did not believe in the New Zealander looking upon the ruins of St. Paul's; but rather looked forward to Windsor Castle becoming a West-End mansion, and the villas of the metropolis flourishing on the hills of the White Horse. No community ever decayed in which the poorer classes could earn a reasonable independence in free competition with all the world.

On Capital Punishments and their Influence on Crime. *By* Henry Ashworth.

From time to time, under the ever-varying condition of our people, an adjustment of punishment for offences has been determined in some way or other by human judgment, and, for the most part, the punishment inflicted has been greatly in excess of the magnitude of the offences committed. The extremity of this policy would appear to have been reached in the time of Henry VIII., during whose reign it has been stated that the incredible number of 72,000 persons were executed for the crime of theft alone, besides those who suffered death for treason and other grave offences. So fearful an amount of legalized slaughter, committed on a population so small, was calculated to have had a most impressive effect. And yet what do we find? Sir Thomas More, writing at that period, says, "Although so many were trussed up, a man could not travel from his own home without fear of being either murdered or robbed." It has been represented that Queen Elizabeth expressed her surprise that men would be committing crimes at the foot of the scaffold; and by way of corrective of this gross sinfulness of her people, she gave orders that upon discovery of the offenders they should be hanged without benefit of clergy.

During the reign of the Stuarts and some of the Brunswick family, the number of capital offences was gradually increased to the extent of 220, and the pecuniary amount for the stealing of which death was inflicted descended to as low a sum as five shillings. Coming nearer to our own day, the prevailing sentiment in relation to almost all offences continued to rest upon the theory of the Legislature, that it was needful to hang men by way of example, in order to prevent others committing crimes. In the year 1786, James Holland, of Kirkham, was condemned at the Lancaster Assizes as a "croft breaker," having stolen 30 yards of cotton cloth, of the value of £3, from the bleach grounds of Mr. Thweat, of Burnden, near Bolton. He was conveyed in a cart from the Castle of Lancaster to the town of Bolton, and was executed there on the 18th September, 1786. Such was the avowed purpose and determination that the most should be made of the impressive effect, that the employers of the neighbourhood had their servants and work-people assembled on the spot to witness the spectacle; and upon the following Sunday the Rev. E. Whitehead, vicar of the parish church, improved the occasion by a sermon upon the recent execution. Taking a retrospective review of the foregoing exposition of one of the 220 cases in which the extreme penalty of the law might be inflicted, the tariff of liability reduced to five shillings, and a theory of punishments calculated to inspire a terror of crime, how humiliating is the commentary of the reverend vicar, that "criminals daily increase, and rapine and villany are at their utmost summit!" Indeed, it could no longer be doubted that there had been existing a grievous misapprehension of what were the most judicious and enlightened means to secure the end designed. Following a disclosure of the notoriously ill success of extreme punishments, a committee was formed in London about the year 1808, to afford assistance to Sir Samuel Romilly, M.P., in obtaining the amelioration of our criminal code; and their exertions were gradually successful. One offence after another ceased to be capital, and a change in our penal code was more and more urgently demanded. Public discussion of the subject brought about the acknowledgment, with all the array of a new discovery, that it was not so much the severity as the certainty of punishment which deters men from the commission of offences. The difficulty of procuring the repeal or even some mitigation of our antiquated penal statutes lay with the Legislature, and the character of the obstruction offered will be estimated by reference to a few only of the accounts of the proceedings. In the session of 1810, Romilly succeeded in carrying through the House of Commons the repeal of the law which made it a capital offence to steal the value of 5*s.* in a shop. The House of Lords threw out the bill by a majority of 31 to 11, and in this majority there were six bishops and one archbishop. From a beginning so inauspicious to look upon, the progress of any salutary change could not be very rapid, and it was in 1833 that Lord Suffield appealed to their Lordships on the following astounding statement:—"I hold in my hand a list of 555 perjured verdicts delivered at the Old Bailey in 15 years, for the single offence of stealing from dwelling-houses; the value stolen in these cases being sworn above 40*s.*, but the verdict returned being reduced by the jury to the value of 39*s.* only." What was the result of this appeal? A change in the law was effected; and Mr. Charles Phillips, in a remarkable pamphlet on capital punishments, published in 1858, somewhat facetiously informs us,—"It did not amount to a repeal, but to an acknowledgment that man, made in the image of his Maker, had risen in the money market; and thereupon human life was advanced by statute from £2, the sum at which it then stood, to £5, being a rise of 60*s.* per head." The effect of this change in the law, as might reasonably be expected, was, that in like manner juries had recourse to an exceptional verdict of £4 19*s.* Sir Fitzroy Kelly stated in Parliament in 1840, "That a few years before there were nearly 200 capital offences on the statute-book; now there were only 14, and that there had been no increase of crime since the repeal." Mr. Hume also remarked, "That in no instance had offences increased in consequence of the mitigation of the punishment; on the contrary, there had been a decrease; so that, in future, capital punishments would be but an unnecessary sacrifice of human life." It will hardly be necessary to offer the remark that the security of property and the good order and general welfare of the community are the great objects of government;—how gratifying is the acknowledgment that these are now being upheld with greater safety and without involving any sacrifice of human life, even of the meanest of our fellow-subjects! The people of Lancashire do not feel indifference, but, on the contrary, they rejoice with the rest of our countrymen in the mitigation of our penal enactments; and, upon an occasion such as the present, it may be allowable, and not inappropriate, if we close this review of the subject by some brief reference to the effects, as they have been disclosed by the criminal records of our own county. From a Parliamentary paper, it appears that in the course of 22 years, from 1798 to 1818, both inclusive, there were in Lancashire 153 executions, more than 50 of which were for offences connected with forgery; and let it be borne in mind that the population of the county, in 1801, was only 672,565. In the last 22 years, the population of 1861 being 2,428,744, or nearly fourfold, the number of executions has been reduced to 16, and these for murder only. It may be insisted that any such comparison as that of the number of executions does not afford conclusive evidence of the diminution of crime; and that, if possible, some other data, affording more minute particulars, ought to be adduced in support of this assumption. It is well known that in the early part of the present century there were not in existence the means of collecting the needful information in the same careful manner as is now annually prepared by the county constabulary. In endeavouring to account for the presence or the absence of crime, it will be admitted that the employment of the executioner as a moral teacher has utterly failed, and that the enactment of stringent laws has not prevented the onward course of crime. When we come to consider the conditions tending to crime, it is well known that the harassing effects of poverty have been but too frequently the originating cause. Under a pressure so severe, how hopeless would be the attempt to enforce the conviction that "honesty is the best policy;" whilst, on the contrary, every one would admit that the meliorating influence of well-paid employment, cheap food, and command of enjoyment, tends to diminish crime and to exalt the character of a people.

The Progress of Science and Art as developed in the Bleaching of Cotton at Bolton. By Henry Ashworth.

Having traced the art of bleaching from its commencement to the present time, and described the present process, Mr. Ashworth continued to say that, by an art which half a century ago was almost unknown, and by the agency of our coal as fuel, we have succeeded in converting certain products which we dig from under our feet, such as salt, pyrites, and lime, into one of the most important branches of manufacturing chemistry. These discoveries in chemistry may appear extraordinary, although they are not more important in the economy of bleaching than are the mechanical arrangements which have superseded the exposure of labourers, in all states of the weather, to the accustomed drudgery of the "crofters" of old. The "crofters," of whom we have spoken, bore the appearance of remarkably strong men; their working dress was of thick white flannel, called "gladding;" the cut of the coat was peculiar, having a loose, open appearance, and a low, flat collar, on which the shirt-collar usually rested. They had their necks uncovered; and, their employment being so much exposed to moisture, they seldom wore stockings. Altogether, they assumed a bearing of unconcern about the state of the weather, and were quite regardless of the splashing of water. Their employment consisted mainly in the handling of wet cloth, and in removing it, either by hand or by wheelbarrows, from one operation to another. Perhaps the most distressing part of their labour was that of carrying upon their shoulders a pile of wet cloth, rising to some height above the head, which they conveyed to some considerable distance in the fields, and spread upon the grass. In the severity of the winter season there would be drippings from the cloth, forming icicles, which would be adhering to the skirts of their clothing. It has been through a succession of mechanical inventions that these laborious operations have been dispensed with, and one after another they have been handed over to the power of the steam-engine. The result has been that the time required for the operation of bleaching is now about as many days as formerly it required weeks to accomplish. Honour to British genius that these advantages have been derived to our country!

The general public will, no doubt, feel curious to ascertain whether any and what proportion of the money-saving thus effected has reached the consumer; some other portion of the public will inquire in what extent the advantages thus achieved by science and art have been shared by the operative class employed,—it is not expected that much concern will be manifested about the interests of the proprietor; and it is not unreasonable to suppose that a still more minute inquiry will be raised about the "human machine," more especially whether, during the progress of these advances in manufacturing art, the material, moral, and intellectual condition of the working class has been made to keep pace with all these improved manipulations, which, amidst the struggle of changes, have destroyed the character of many employments, but have greatly increased the whole number of persons employed?

The advantages shared by the consumer will easily be reckoned. We have before us a printed card, or list of prices for bleaching, issued by a leading firm in the year 1803. At that time the charge for bleaching a well-known description of cloth was 7*s*. 6*d*. for a piece of 28 yards, and it is now 6*d*. The case of the labourers employed in bleaching 60 or 70 years ago was, as before stated, a very harassing one; they suffered severely from exposure to wet and cold, and, as a consequence, from rheumatism and asthma. The earnings of a "crofter" would be from 10*s*. to 15*s*. per week. Upon wages so scanty, and with some uncertainty of employment, their mode of living was necessarily inexpensive. Oatmeal was the staple commodity of their food. They used it as porridge; their bread was of oatmeal, either in leavened oat-cakes or baked in the form of a loaf called jannock, which is said to have been introduced by the refugee Flemings; and animal food, with the exception of bacon, was seldom found at the working-man's table. Now-a-days, the workmen in bleach-works perform all their work indoors, and are therefore no longer exposed to the coldness and moisture of the former period. The wages are increased in a proportion which cannot easily be estimated, and their employment is one of great regularity. They have nearly ceased to consume oatmeal; jannock is unheard of; oat-cakes are seldom seen; and their tables are now daily spread with wheaten bread, animal food from the shambles, and all the other articles which usually enter into the consumption of families in the other grades of life.

The social condition of the operative bleacher of early times cannot easily be separated from the rest of the working population of that day, neither could they now be described in any other manner than that which would apply to the operatives around them in other pursuits. We may refer to their modes of pleasure-taking as affording in itself a very appreciable indication of the past and present. The amusements which formerly prevailed were rude and boisterous; now they are more refined and intellectual. Bull-baiting, bear-baiting, and cock-fighting were amongst the common amusements of the day, especially at the wakes and fairs. The game of foot-ball was a very favourite one, so much so that the people of one place would make selection of their combatants and have them pitched against those of some other place, and these would contend in very ardent strife for the renown of mastery. Indeed, so very popular was this game, that a match at foot-ball was upon one day in the year tolerated by the inhabitants in the streets of Bolton. The whole of this is now given up. The game of cricket is becoming a popular one, and others equally harmless in their character are being introduced. Seventy years ago, Sunday-schools had made but slight progress. There were but few persons who could read, still fewer who could write; and when any one received a letter, he had to carry it away, perhaps a good many miles, to find a scholar who could read it. At the present time, Sunday-schools abound, day-schools are numerous, and the affair of carrying away a letter in search of a scholar may now with much complacency be put down as among the reminiscences of seventy years ago.

On the Influence of Density of Population on the Fecundity of Marriages in England. By R. H. Bakewell.

A Glance at the Cotton Trade. By Thomas Bazley, *M.P.*

A century ago the population of Manchester was below 30,000, whilst now 350,000 persons reside in and occupy it. Population and wealth have wonderfully increased and ramified to other places; but now, in the zenith of prosperity, a mysterious hand has written upon our walls the words of caution and of admonition. During the last fifty years upwards of 20,000,000,000 pounds weight of cotton from all sources have been consumed in Great Britain, and the value would be probably not less than £750,000,000 sterling, or might equal a sum of the amount of our National Debt, the chief supply having been obtained from the United States of America. Upon a fair computation, the import of that material, which has so largely employed the capital and labour of this country, has yielded a profit of not less than £1,000,000,000 sterling to the people of the United Kingdom within that period. The wonder is, that so large a supply of cotton could be procured from that one source, the United States; and when we reflect that this country possesses a monopoly of the vast extent of territory found in the whole world capable of producing this raw material, the inference is most palpable, that there has been developed the most successful agricultural industry in the States of America which has been ever either contemplated or realized; whilst in British colonies and dependencies apathy and neglect have prevailed. If the legislature had little sympathy with the great industry of Lancashire, the interests of our foreign possessions might have induced our rulers to stimulate productions in them which would have found compensating markets at home. The advocates of large and of independent supplies of raw cotton, from all possible sources, have never desired Governmental favours, their object having been to promote the removal of repressing obstacles, and to procure, by the aid of a sound colonial policy, at least a fair share, in proportion to the extent of our foreign possessions, not only of cotton, but of every other product which they might more abundantly have yielded. During the last year the consumption of cotton in Great Britain was 85 per cent. from the United States, 8 per cent. from other foreign sources, and 7 per cent. from British territory. The present position of the trade is most precarious and dangerous. Existing stocks and prospective supplies of cotton may enable the mills to be worked into the spring of next year, at moderately full time; but afterwards, unless supplies be received from the United States, independent sources can only furnish the means of keeping the mills at work little more than one day in the week. With the growth of this industry 5,000,000 of our population have become, directly and indirectly, dependent upon it for their subsistence; and the productiveness of their capital and labour, including the raw material, was for the last year nearly eighty million pounds sterling. Of this large value twenty-five millions of cotton manufactures were absorbed in the consumption of the people of the United Kingdom, and there remained for exportation fifty-five millions. The estimated capital engaged in its fixed and floating investments is two hundred million pounds. Now, when we contemplate the vast interests involved in this surprising trade, seeing that the people employed and connected with it exceed the population of the kingdom of Belgium, of Holland, and of Portugal,—that the national treasury receives from it an amazing sum in aid of the expenses of the State,—that a commercial marine of unparalleled magnitude derives support from it,—that the comfort and happiness of the labourers employed in it are imperilled by any indications which threaten to disturb its existence and prosperity,—and that its suspension or serious curtailment would even endanger the general weal,—we may well inquire what efforts have been made to sustain the usefulness, prosperity, and permanency of this source of national riches. That the cotton trade should have rested chiefly upon the one supply of the States of America for its very means of existence, every good and every wise man has deplored; but that to produce that supply the portion of the human family which is most defenceless should be held in the degradation of slavery is abhorrent to the feelings of the righteous, of the humane, and of the benevolent. Most effectually to suppress slavery will be to supersede the necessity for the labour of the slave; and if the chiefs of Africa could be induced to cultivate sugar, cotton, and tobacco upon their own soil, they need not expel and degrade their labourers.

The author added remarks on the effects of the commercial policy of the United States, and affirmed that this country has been paying a tribute of five million pounds sterling per annum to those States in excess of the price at which cotton could be remuneratively produced and sold. With the convulsion which exists in America, with the adverse commercial policy dominant there, and with the inhuman system of slavery which prevails in the cotton-producing districts, what are the duties which devolve upon our governing and mercantile classes? If by the convulsion of the States we are taught our national as well as commercial duties, the lesson will be ultimately beneficial. Whether it has been wise for our Government to see continually increasing the dependence of this great trade upon the one chief supply of its raw material, and that source adverse in interest and oppressive to its own labour, we can only answer in the negative. With the East and West Indies, with tracts in South, East, and West Africa, and with land in Australia as extensive as Europe, capable of growing cotton from the lowest to the highest qualities, it is a national reproach to us that we have permitted our own fields to be uncultivated, and that our spinners and manufacturers have been driven by necessity to consume the produce of slavery. Lacking the means of communication and of irrigation, the resources of the East Indies remain in much the same dormant condition in which they have been for two thousand years; but brighter prospects are opening in that great dependency,—railways are being constructed, canals formed, river navigation improved, and works of irrigation promoted. One great defect, however, is retained with perverse tenacity. The tenure of land is obstructive alike to the rights of individual ownership and to its effective cultivation. Without doing the slightest wrong to the holders of any land, its equitable transfer might be sanctioned, and a landed proprietary as influential as in our own country might be established. Protection to life and the rights of property, with every other just adjunct of good government, will inevitably lead to prosperity. Small supplies of cotton, as good as that obtained from New Orleans, are now received from India, and the cotton of this vast dependency is certainly improving; but whilst, from a combination of circumstances and causes, the ryot of India is only paid 12*s.* per acre for his crop of cotton, and the American cultivator can obtain £12, the energy and capability of the former cannot be developed. Supposing efforts to be made commensurate with indicated difficulties, all the common cottons, or 75 per cent. of the consumption of Great Britain, might be obtained from India in a couple of years. From Egypt the supply of cotton may increase, but there the withering influence of the despot retards its extended cultivation, though the spirited, energetic, and successful enterprise of Mehemet Ali is an example deserving the imitation of better men. He introduced that agricultural industry into his viceroyalty, and founded a fountain of wealth whence flow millions of annual income to the advantage of Egypt. For all the finer, higher, and better classes of cotton, from New Orleans, Brazil, and Egyptian, to the most beautiful Sea Island, Queensland, in Australia, might quickly afford all requisite supplies. That territory alone, besides sustaining the population of Europe, could easily be made to produce all the cotton now consumed in the world; but so sweeping a change and enlarged production need not be deliberated upon, the facts being only referred to as illustrating the powers of that colony. In seeking from the Government the development of the resources of the colonies, the twofold advantage would arise by which that power would financially be greatly benefited, alike at home and in the colonies. Government must set its colonial house in order. Land grants for beneficial purposes should be free, facilities afforded for emigration, public works promoted, and prosperity will follow in the train. Capitalists, merchants, and manufacturers, whose investments are largely embarked in the cotton trade, have duties devolving upon them. These bodies are known to have large investments in foreign railways, in the cultivation of sugar and other products, and in many dubious securities; but in the cultivation of the staple raw material of their own pursuits they have not ventured to embark. Last year the cotton trade contributed to capital and labour fifty million pounds sterling, and in the last fifty years the aggregate reward has been one thousand millions. Surely from these treasures might be spared some pittance of capital to free the negro, and to ensure still greater prosperity to industry. Supposing the Government of our country to be willing to make all the preliminary arrangements which will contribute to the security and profit of capital invested in cotton-growing, the clear duty of the class referred to will be to enter upon investments with no niggard hand; and, for their encouragement, it may be mentioned that very recently an extensive Louisiana cotton-planter has asserted that he could grow cotton at 3*d.* per lb. which is now worth 9*d.* per lb. in Liverpool, and of course he has had to buy his labourers, and afterwards to sustain them. The confessed profit is 200 per cent.; but, in all sobriety of judgment, cotton-growing would afford 100 per cent. of recompense. Here, then, the governing, the capitalist, the mercantile, and the manufacturing classes have duties in common to perform, and from which none of them should withhold their willing help. Upon this subject the warning voice has been long and often heard, and the present embarrassment in cotton supplies has been anticipated. Having, therefore, been forewarned, may this great and world-benefiting industry be fore-armed!

On Ten Years' Statistics of the Mortality amongst the Orphan Children taken under the Care of the Dublin Protestant Orphan Societies. By the Rev. W. Caine, *M.A.*

There are two of these societies in Dublin, one for the children of parents both of whom were Protestants, the other for the children of mixed marriages.

Their distinguishing peculiarity is, that the children taken under their care are not congregated together in one large building, but are placed with poor Protestant families in Wicklow and other counties in Ireland.

A great saving is effected by this plan. Each child costs only between £5 and £6 per annum. In the workhouse each child would cost about £9.

Very great care is used in the selection of the families in which the children are placed. The minister of the parish reports to the Committee in Dublin at stated times whether they are properly attended to, and members of the Committee visit them every year. This supervision tends to promote *cleanliness and sobriety* in the families with which the orphans live, as they would be at once removed if there were any deficiency in these particulars.

The happy result is seen in the exceedingly small amount of mortality amongst the children. Their ages range from 6 months to 14 or 15 years.

In the Protestant Orphan Society the mortality during the last ten years has been as follows:—

1851 ..	375 children ..	1 died.	1856 ..	420 children ..	5 died.
1852 ..	400 " ..	3 died.	1857 ..	420 " ..	2 died.
1853 ..	400 " ..	3 died.	1858 ..	420 " ..	3 died.
1854 ..	400 " ..	3 died.	1859 ..	420 " ..	2 died.
1855 ..	400 " ..	3 died.	1860 ..	432 " ..	1 died.

The average number of children during the ten years has been 409; the average number of deaths only $2\frac{1}{2}$ each year—not 1 per cent. per annum.

In the other society, called the Protestant Orphan Union, the mortality has been as follows:—

1851 ..	36 children ..	1 died in these 4 years.	1856 ..	109 children ..	1 died.
1852 ..	47 " ..		1857 ..	120 " ..	1 died.
1853 ..	61 " ..		1858 ..	132 " ..	1 died.
1854 ..	87 " ..		1859 ..	150 " ..	1 died.
1855 ..	105 " ..	1 died.	1860 ..	165 " ..	2 died.

The average number of children during the last 10 years has been 101. The average number of deaths has not been 1 per cent., as there have been only 8 deaths in the ten years.

Contrast this mortality with that of the children in English and Scotch cities. In Manchester 50 per cent. die before they are 5 years old; in Glasgow, 54; in Edinburgh, 38½; and in Aberdeen, 32 per cent. And throughout the kingdom half the children die before they reach the age of 14 years.

The exceedingly small mortality amongst the orphan children under the care of the Dublin Protestant Orphan Societies shows what attention to sobriety and cleanliness, on the part of parents and nurses, and a proper supply of pure air would effect in this country. It also shows to what a fearful extent murder prevails—the murder of innocent children—and the injury which accrues to our own country and the world from the loss of the services and the labours of those thus cut off in childhood, and thereby prevented from benefiting their country and the world, which they in most instances would have done, if they had not met with untimely deaths at the hands of their intemperate and uncleanly parents, and through the neglect of the community at large.

On the Progress of Manchester from 1840 *to* 1860.
By DAVID CHADWICK, *F.S.S., Assoc. Inst. C.E., Secretary of Section F.*

Mr. David Chadwick stated that, having been requested by the Committee of Economic Science, at the last meeting of the British Association at Oxford, to prepare a paper on the progress of Manchester and Salford during the twenty years 1840–60, he would consider *seriatim* the increase of population and that of the principal manufacturing towns in the country; the annual value of property; the proportion of parliamentary representation to persons and property; the trade of the district, with particulars of cotton imports and exports of manufactured goods; improvements in cotton-machinery; wages of the operatives, with a comparative statement of the cost of food and clothing, and facilities for their social, physical, and intellectual advancement; the municipal and local governments of Manchester and Salford, noticing the taxation and local improvements effected within the period indicated.

Mr. Chadwick stated the population of the principal towns in Lancashire at each decennial period from 1801 to 1861, showing an increase in Manchester and Salford, from 94,876 in 1801 to 311,269 in 1841, and to 460,018 in 1861, the rate of progress being 47·79 per cent. in the last twenty years, and 384·86 per cent. in the last sixty years. Taking the twelve principal towns of the county during the same period, the increase was from 291,281 in 1801 to 929,405 in 1841, and to 1,417,662 in 1861. Comparing this progress with that of the entire county, and of England and Wales, the rate of increase has been, in the twelve town districts, from 1841 to 1861, 52·53 per cent.; and 1801 to 1861, 386·7 per cent.; in the county, in twenty years, 45·09 per cent.; and in sixty years, 260·71 per cent.; and in England and Wales, in twenty years, 26·06 per cent.; and in sixty years 125·6 per cent. In 1801 the population of Lancashire was 7·68 per cent. of the total population of England and Wales, or nearly 1-13th part thereof. In 1861, the per-centage had increased to 12·29, or nearly 1-8th part thereof.

The population in each township of the parish of Manchester, and in the parliamentary boroughs of Manchester and Salford, in 1851 and 1861, was then detailed, with the per-centage of increase in the ten years. It appeared that, owing to the extension of warehouses, &c., used only in the daytime, and abandoned at night, the population of the township of Manchester had decreased 1·04 per cent. during the last ten years, whilst that of all the remaining townships had increased, Chorlton-on-Medlock being the lowest (25·99 per cent.) and Bradford the highest (124·11 per cent.), the total increase in the parliamentary borough being 13·09 per cent. The population of the city proper (not including Bradford, Newton, and Harpurhey) had increased 11·52 per cent. In Salford (parliamentary and municipal) the total increase in population was 20·33 per cent., detailed thus: —Salford township, 11·95; Broughton, 38·72; Pendleton, 46·93; part Pendlebury, 87·46.

This rapid increase could only be accounted for on the supposition that the occupations of the people in the manufacturing districts are more congenial, and afford better remuneration, than agricultural pursuits.

Mr. Chadwick then referred to a paper read at the last meeting of the British Association in Manchester, in 1842, by Mr. Henry Ashworth of Bolton, showing that the total value of property in Lancashire, in 1692, was £95,242; and in 1841, £6,192,067, being an increase of 6300 per cent. in a century and a half,—the proportions of the increase being, in the three agricultural portions of the country, 3500 per cent.; and in the three manufacturing hundreds (Blackburn, Salford, and West Derby), 7000 per cent. The total assessable annual value of property in the county was (as shown by a parliamentary return), in 1860, £10,458,243, being an increase of £4,266,176 in twenty years, or 69·35 per cent. The total assessable annual value of property in England and Wales was, in 1860, £103,462,535,—that of Lancashire being therefore equal to 10·14 per cent. thereof.

Referring to the question of representation, it was shown that prior to 1832, Manchester, Salford, and many other of the great towns of Lancashire were unrepresented in Parliament, but that the Reform Bill gave them 26 members (now increased to 27). England and Wales returned 500 members, being one member for £206,925 annual value of property, and 40,123 of population; whilst Lancashire, with its 27 members, had only one member for £387,342 value and 91,281 population. Thus, although Lancashire constitutes 12·29 per cent. of the population, and 10·14 per cent. of the annual value of property in England and Wales, the number of its parliamentary representatives is only 5·4 per cent. of the number returned for England and the Principality.

The great staple trade of the district was next considered. The tables under this head showed cotton imported into the United Kingdom from 1842 to 1845 inclusive (four years):—From the United States, 2,064,128,400 lb.; all other countries, 608,476,800 lb.: total imports, 2,672,605,200 lb. (estimated at 400 lb. per bale). In 1846 to 1848 (three years): United States, 1,366,796,172 lb.; other countries, 288,787,878 lb.; total, 1,655,584,050 lb. Whilst in the three years ending 1860, the figures were as follows:—United States, 2,910,835,648 lb.; all other countries, 740,434,352 lb.; total, 3,651,270,000 lb. The imports were, in 1846, 467,856,274 lb.; and in 1860, 1,390,938,752 lb., being an increase in fourteen years of 197 per cent. Of cotton imported in 1846, the United States supplied 86 per cent., and all other countries 14 per cent.; in 1860, the United States, 80¼, and other countries 19¾ per cent. Next followed a statement of cotton consumed, and manufactured goods produced in Great Britain, in 1830, 1840, 1850, and 1860; which showed, 247,600,000 lb. of raw cotton consumed in 1830, against 1,083,600,000 lb. in 1860; the manufactured goods produced being 182,954,658 lb. in 1830, as against 886,256,345 lb. in 1860. Total manufactured goods, in 1830, 914,773,563 yards; in 1860, 4,431,281,728 yards, or 2,517,774 miles—a quantity which would wrap 100 times round the globe! Total value of cotton goods produced, upwards of £77,000,000, a sum exceeding the total revenue of the United Kingdom. The difference between the value of cotton manufactured and yarns exported, and the total cotton imports, leaves 16¼ millions as the value of labour, &c., left in the country from exports of cotton manufacture alone—exceeding our total exports of woollen goods and yarns, and more than double our exports of silk and linen manufactures. As a companion to the foregoing statement, Mr. Chadwick also gave the imports of cotton, wool, silk, hemp, and flax, in various years, from 1790 to the present time, annexing a table showing the number of factories existing in the United Kingdom in 1856, with other particulars therewith connected. Number of textile factories, 5117; spindles, 33,503,580; power looms, 370,195; total persons employed, 682,497. The motive power employed in 1856 appears to have been:—steam = 137,711 horses; water, 23,724; total horse-power, 161,435 (no later connected returns had been issued). Number of spindles at work in cotton factories in 1860, 33,862,500, turning off 32 lb. of yarn per spindle per annum. Deducting the exports in yarn, 27,695,511 spindles, or 369,273 looms, remain. Total estimated value of spindles and looms employed in the manufacture of cotton in Great Britain in 1860, £41,247,960. Spindles, 84,656 horse-power; looms, 24,685. Total, 109,341; consuming 639,586 tons of coals in the year. Increase in spindles and looms in the four years, 20 per cent. Calculated in the same ratio, the number of operatives would be 455,055, which, at 9*s.* 6*d.* weekly average wages, would give the amount paid in 1860 as £11,239,857. Our imports of merchandize and bullion amounted in the same year to £233,626,839; exports, £191,205,421; or a total representing considerably more than one-half of the national debt. A table was then produced showing the exports from the United Kingdom of ten of the principal articles of British and Irish produce for each year from 1846 to 1860. From this it appeared that the export of cotton goods from 1846 to 1860 increased from 1062 million yards to 2765 million yards, or 160 per cent., whilst the value of cotton manufactured goods exported was, in 1846, £17,717,778; and in 1860, £42,141,505, or an increase of 138 per cent. The increase per cent. on the other articles referred to was as follows:—

	Quantity.	Value.
Coals and coke	189	241
Cotton twist and yarn	22	25
Iron (cast and wrought)	233	190
Linen manufactures	64	70
Thread for sewing	84	106
Linen yarn	60	
Woollen cloths	98	87
Mixed stuffs, flannels, &c.	246	152
Total woollen manufactures	—	92
Woollen and worsted yarn	219	323
Machinery of all kinds	—	243

The estimated number of spindles used in cotton factories, in 1840, was seventeen millions; in 1856, twenty-eight millions; in 1860, thirty-three millions. Estimated consumption of cotton in 1840, 9,400,000 lb.; 1856, 17,466,400 lb.; 1860, 18,400,000 lb. Spindles made weekly in 1860, 60,000, or (say) three millions in the year; of these, one and a half millions would be for home, half a million for replacement, and a million for foreign orders. Increase in the number of spindles in the year, one and a half millions, equivalent to the production of 1,124,000 lb. of 23's yarn. The annual increase in the cotton-supply required to meet the increase of machinery in use in the United Kingdom, at this rate, would be 3100 bales, or 1,240,000 lb.; to meet the increase of machinery made in the United Kingdom for home and foreign use (deducting replacement item), 4687 bales, or 1,874,800 lb. The improvement effected in the various classes of cotton and other textile machinery during the last twenty years was then noticed. Since the invention by Mr. Richard Roberts of the self-acting mule (known as "Sharp's Self-acting Mule"), it was stated that there had been no single improvement of equal importance made in the economy of the cotton-manufacture; but many very important and valuable minor improvements in working, in economizing labour, in increasing speed, and thereby increasing the production, both in spinning and weaving, had been effected. In willow- and blowing-machinery, and carding-engines, the increase in production had been 20 to 25 per cent.; saving of labour, 20 per cent.: drawing-frames, increase the same; saving of labour, 100 per cent.: slubbing- and roving-frames, increase the same; saving of labour, 40 to 45 per cent.: spinning- and doubling-machinery, increase in length of machines, 100 per cent.—average length of machines in 1840 being 480 spindles, and in 1860, 960 spindles; saving of labour, 50 per cent.: weaving-machinery, increase in production (in sizing-machinery, 150 per cent.), looms, 25 per cent.; saving of labour, 40 per cent. Improvements of great importance had also been effected in other branches, such as the introduction into general use of chlorine, in bleaching; the new dyes (magenta, &c., and from gas tar); the sewing-machine, for making clothes, shoes, saddlery, and numerous other articles. From a comparative statement of the actual increase of work done by cotton- &c. machinery in 1841 and 1861, it appeared that the estimated number of 33,000,000 spindles in 1860 would do as much work as 37,263,600 in 1840; but as there were only about 17,000,000 spindles in 1840, it followed that the increase of the producing-power was 119·2 per cent. in twenty years.

The following statement of the proportion of adults and children in a cotton-mill of 500 workers, and their average weekly wages, was submitted:—

Proportion of each class of Adults and Children in a Lancashire Cotton-Mill of 500 Workers, and their average Weekly Wages in 1860.

Class of Work.	Men.	Women.	Boys.	Girls.	Total.
	No.	No.	No.	No.	No.
1. Stokers, engineers, lodge-keepers, warehousemen, mechanics, and porters...	20	2	5	..	27
2. Cotton-mixing and blowing..........	7	..	1	..	8
3. Carding..............	17	36	4	15	72
4. Self-acting mule spinning..............	24	..	10	1	35
5. Throstle spinning, winding, and warping..............	7	39	12	11	69
6. Power-loom weavers ..	10	173	..	92	275
7. Beaming, twisting, and sizing.........	10	1	1	2	14
	95	251	33	121	500
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Average of total wages of workers in all departments taken together.............	87 17 6	127 11 10	11 11 0	30 5 0	257 5 4
Average wages to each person..............	0 18 6	0 10 2	0 7 0	0 5 0	0 10 3½

Mr. Chadwick then referred to his recent investigations and report on the rate of wages in England in 200 trades and branches of labour (see 'Journal of the Statistical Society of London,' March 1860), and stated that the advance of wages in the various branches of the cotton trade, during the last 20 years, had been from 10 to 25 per cent.; in the silk trade, about 10 per cent.; in the building-trades, from 11 to 32 per cent.; in the mechanical trades, from 10 to 45 per cent. Reductions had been made in many branches of trade where the skill of the workmen was no longer required by the improvements in machinery.

In 1840 the labour in the cotton-mills was 69 hours per week, and in 1860 it was only 60 hours per week.

Whilst the wages of the operatives have materially increased, the cost of food and clothing has been greatly reduced, as shown by the following Table (p. 213):—

Mr. Chadwick here contended for the prosperity of Liverpool and other places having been largely dependent upon and promoted by the extraordinary extension of the cotton trade of the manufacturing portions of Lancashire; and then summarized his paper thus far, asking, first, whether the increase of population in manufacturing towns was a healthy sign and likely to continue; second, whether the trade was not unduly stimulated, or was generally sound and healthy; third, could we expect a continuance of the present demand for cotton goods, &c., so as to justify the anticipation that the increase would continue in the same proportion as heretofore; and fourth, whether a sufficient supply of the raw material, cotton, could be found to meet the yearly increasing demand.

The local government of Manchester and Salford, their corporations, police, sanitary, charitable, provident, educational, and other institutions were then referred to. The progress of Manchester was traced from 1301, and the neighbouring borough from 1230; each being municipally governed by 16 aldermen and 48 councillors. In Manchester, in 1839, the assessable value of property was £669,934, and the total borough-rate £33,515; whilst in 1860 the amounts were £1,203,505 and £68,147 respectively. In Salford, the assessable value of property, in 1844, was £161,734, and the borough-rate £4877; whilst in 1860, £346,601 and £10,583 were the respective amounts. An exceedingly interesting table was produced, prepared by Mr. T. Lings, exhibiting the assessments, amount of poor-rate, and the several ways in which the latter had been expended during the last forty years.

Statement of the Average Weekly Expenditure in 1859–60, of a Family consisting of Husband, Wife, and Three Children, whose Total Wages averaged 30*s.* per Week:—as compared with the Cost of the same Articles in 1849–50 and 1839–40.

Articles.	Expenditure in 1859–60.		Cost of same Articles in 1849–50.		Cost of same Articles in 1839–40.	
(I.) Bread, Flour, and Meal.		*s.* *d.*		*s.* *d.*		*s.* *d.*
8 4 lb. loaves (32 lb.)...	5½*d.* per 4 lb.	3 8	6*d.* per 4 lb.	4 0	8½ per 4 lb.	5 8
½ a peck of meal.........	1*s.* 8*d.* per pk.	0 10	1*s.* 6*d.* per peck.	0 9	1*s.* 4*d.* per pk.	0 8
½ a doz. (6 lb.) flour ...	1*s.* 8*d.* per doz.	0 10	1*s.* 10*d.* per doz.	0 11	2*s.* 4*d.* per doz.	1 2
		5 4		5 8		7 8
(II.) Butcher's Meat and Bacon.						
5 lb. of butcher's meat..	6½*d.* per lb.	2 8½	7*d.* per lb.	2 11	6½*d.* per lb.	2 8½
2 lb. of bacon	8*d.* "	1 4	9*d.* per lb.	1 6	8*d.* "	1 4
		4 0½		4 5		4 0½
(III.) Potatoes, Milk, and Vegetables.						
2 score of potatoes	1*s.* per score	2 0	1*s.* per score	2 0	1*s.* per score	2 0
7 quarts of milk	3*d.* per quart	1 9	3*d.* per quart	1 9	3*d.* per quart	1 9
Vegetables	...	0 6	...	0 6	...	0 6
		4 3		4 3		4 3
(IV.) Groceries, Coals, &c.						
½ lb. of coffee	1*s.* 4*d.* per lb.	0 8	1*s.* 4*d.* per lb.	0 8	2*s.* per lb.	1 0
¼ lb. of tea	4*s.* "	1 0	4*s.* 4*d.* "	1 1	6*s.* "	1 6
3 lb. of sugar	5*d.* "	1 3	5*d.* "	1 3	7*d.* "	1 9
2 lb. of rice	3*d.* "	0 6	3*d.* "	0 6	4*d.* "	0 8
1 lb. of butter	1*s.* 1*d.* "	1 1	1*s.* "	1 0	1*s.* 1*d.* "	1 1
2 lb. of treacle	2½*d.* "	0 5	3*d.* "	0 6	4*d.* "	0 8
1½ lb. of soap	4*d.* "	0 6	5*d.* "	0 7½	5*d.* "	0 7½
Coals, 1*s.*, candles, 6*d.*	...	1 6	...	1 6	...	1 6
		6 11		7 1½		8 9½
Total cost of food and fuel	...	20 6½	...	21 5½	...	24 9
Rent, taxes, and water	...	4 0	...	4 0	...	4 0
Clothing	...	3 0	...	3 0	...	3 0
Sundries	...	2 5½	...	2 5½	...	2 5½
		30 0		30 11		34 2½

This return showed that the annual value of property assessed to the poor-rate had increased from £307,510 in 1820 to £597,921 in 1840, and to £789,203 in 1860,—the increase in the value of property being, in the first twenty years (1820–40), 94·44 per cent.; and in 1840–60, 31·99 per cent. The annual amount in the pound of the poor-rate on the annual value of the property during such 40 years had ranged from 1*s*. 4*d*. to 6*s*. 8*d*., the average amount in the pound of the poor-rate on the assessable value of property during the whole 40 years being 3*s*. 5½*d*.

Mr. Chadwick stated that he had been unable to obtain from the Manchester Gasworks the necessary figures to enable him to institute a comparison between the years 1840 and 1860, as to the quantity of gas produced, the gas-rentals, profits, &c. He could therefore only furnish a few figures, which might be found of interest:—

The Gas-Rentals were in	1843	£52,800
" " "	1850	85,800
" " "	1860	154,600

In 1860, the price of gas per 1000 cubic feet was 3*s*. 8*d*. to 4*s*. within the city, and 6*d*. to 8*d*. extra outside the city; the gross amount of the gas-profits was £64,779; the total number of gas-meters in use in the city was 30,328; and the number of street-lamps, 7116.

In 1840, the quantity of water supplied by the Manchester and Salford Waterworks Company was 1½ million gallons per day. In 1860, the quantity of water supplied by the Corporation was 11½ million gallons per day. In 1840, the amount received for water supplied was £22,400; in 1860, £72,000. The amount paid for the Old Waterworks by the Corporation was £538,000; and the amount expended in New Waterworks, £827,000. Total cost of Waterworks, £1,365,000.

The Manchester Markets were purchased by the Corporation from Sir Oswald Mosley, in 1846, for £200,000,—the value of property since purchased, and improvements effected, being £63,000. The balance owing to Sir Oswald Mosley and other parties on mortgage, in 1860, was £161,000. The annual income from the markets when purchased in 1846 was about £10,000; in 1860 the annual income exceeded £20,000.

A table showing the work done by the Paving, Sewering, and Highways Committee of the Manchester Corporation for the last thirty years was then produced:—Number of streets and courts paved, flagged, drained, &c., 1502; length of streets, 60 miles; area flagged and paved, about 205 acres. Main sewers constructed, 88 miles; cross sewers and eyes, 49 miles; total about 137 miles. The number of siphon-traps which had been laid in streets, passages, yards, courts, and houses were 12,299. [Mr. Chadwick stated, as an addendum to these tables, that the cost of paving and sewering an area of 960,400 yards of streets in Manchester, from 1830 to 1860, had been £311,623 9*s*.; whilst in Salford, from 1844 to 1860, 232 streets had cost £61,546.]

The criminal statistics of Manchester showed the number of persons apprehended, and how disposed of, for each year from 1841 to 1860. It appeared that, whilst in 1841, with only 317 police officers, there were 2962 convictions out of 13,345 arrests; in twelve months, 1859–60, with 617 as a police force, 4900 were convicted out of 7387 arrested. From a return prepared by Captain Lane, the governor, it appeared that in 1851 there were 303 prisoners in the city gaol. The cost per head per day was 19¾*d*.; the net earnings of the prisoners, £162 in the year, leaving the net cost per head per day, after deducting earnings, 19¼*d*. In the year ending March, 1861, the average number of prisoners was 508; the cost per head per day, 12¾*d*.; the net earnings of the prisoners, £2776 for the year, leaving the cost per head per day, after deducting earnings, 9¼*d*. Two tables related to the local Courts of Record, showing the actions instituted and their results (in Manchester, 1858–60: total writs issued 10,475, for £136,188; in Salford, 5792, for £71,834). Mr. Chadwick then referred to a brief and curious statement of the history, objects, and powers of the Court Leet for the Hundred of Salford (now nearly obsolete in functions), with its public stocks and other chastisements and penalties against "eaves-droppings, waifs, and irregularities on public commons;" "rogues, vagabonds, and sturdy beggars," "card- and dice-playing, and suchlike unlawful games."

The charitable and benevolent institutions of Manchester and Salford were then noticed. Booth's and the other Salford Charities. Manchester Royal Infirmary and Dispensary: in 1840, 19,231 patients, income £8415; in 1860, 25,437 patients, income £13,779. Lunatic Hospital: in 1840, 74 patients, income £2629; in 1860, 109 patients, income £6073. Chorlton-on-Medlock Dispensary: in 1840, 2095 patients, income £487; in 1860, 2242 patients, income £366. St. Mary's Hospital: in 1840, 3455 patients, and £1019 income; in 1860, 4667 patients, and £1212 income. Eye Hospital: in 1840, 1510 patients, and £408 income; in 1860, 2417 patients, £641 income. Clinical Hospital: total patients, 1856 to 1860, 4328; total income, 1858–60, £662. Manchester Institution for Diseases of the Ear: in 1855, 254 patients, and £93 income; in 1860, 1195 patients, and income £83; or £10 less income and 941 more patients. Dispensary for Sick Children: in 1860, 4872 patients, and £2190 income. Salford Royal Dispensary: in 1840, 5149 patients, and £534 income; in 1860, 5762 patients, and £1011 income.

Of the Salford County Court a tabulated return was presented showing the number of plaints entered to have been as follows:—1847, 1754 plaints; 1853, 5019 1860, 10,163; amount sued for in 1860, £16,358. The court sat 17 days in 1847, and 47 days in 1860.

The statistics of services rendered by the Manchester Fire-Brigade, in the thirteen years 1848–60, were also noticed, showing property saved to the extent of £5,900,364, and destroyed, £854,373. There had been no augmentation of the strength of the brigade, which numbered 51 men.

Passing to the consideration of the figures appertaining to the Manchester and Salford Savings' Bank, it was remarked that habits of forethought and prudence had taken a deep hold on the Lancashire mind, in Manchester especially. The number of depositors in 1840 was 13,453; in 1860, 49,227. Total amount deposited: from 1818 to 1840, £1,376,460; from 1840 to 1860, £4,493,065; in 1860 alone, £379,403. Average amount of deposits per annum: 1818–40, £59,846; 1840–60, £224,653. The classification of depositors (as shown in the Association's last report) revealed some highly interesting facts.

The educational was the last branch alluded to by Mr. Chadwick. Manchester (he said) was decidedly great in its Sabbath-school organization. The gathering in Peel Park, on the occasion of Her Majesty's visit, of nearly 80,000 teachers and children, would not soon be forgotten. The eighteenth annual report of the Salford Sunday-School Union (March 1860) gives the number of teachers as 674, and scholars 7766; number of Sunday Schools (exclusive of Roman Catholics, of which no complete record had been received) in Manchester and Salford, 201, comprising about 90,000 scholars—the afternoon attendance averaging about two-thirds, or 60,000. There were in the Sunday-Ragged-School Union 17 schools, with 402 teachers, and 3678 scholars; 35 night-schools, with 1483 scholars; 15 ragged schools had penny savings' banks, in which 1316 children had deposited £278; one of these ragged-schools had also been made a night-asylum for destitute children, besides which there was one school not in the union, with about 300 scholars.

The present average attendance at day-schools in Manchester was stated as 31,923; in Salford, 9925; total, 41,848. And in Sunday-schools, in Manchester, 42,687; in Salford, 16,354; total, 59,041, as particularized in the following tables, prepared for this paper by Captain Palin and Mr. Taylor:—

Return showing the number of Schools of all Denominations within the City of Manchester, and the number of Scholars attending them, in 1861.

Day and Sunday Schools.	Sunday Schools.	Total.	If under Government Inspection, and if Church of England, Roman Catholic, or Dissenting.	Day Scholars.				Sunday Scholars.
				Under 7 years.	Under 14 yrs.	Over 14 yrs.	Total.	
8	2	10	Church of England	463	700	12	1,175	14,904
34	...	34	Ditto, under Inspection	6,040	6,845	45	12,930	
5	...	5	Roman Catholic	570	384	15	969	5,150
7	...	7	Ditto, under Inspection	1,226	1,516	12	2,754	
18	44	62	Dissenting	1,157	1,544	21	2,722	20,803
6	...	6	Ditto, under Inspection	772	1,470	45	2,287	
191	...	191	Private Schools, Academies, and all Establishments not directly connected with a Place of Worship	2,678	5,943	465	9,086	1,830
269	46	315		12,906	18,402	615	31,923	42,687

Return showing the number of Schools in the Borough of Salford, and the number of Scholars attending them, in 1861.

No. of Schools.	If under Government Inspection, and if Church of England, Roman Catholic, or Dissenting.	Day Scholars.				Sunday Scholars.
		Under 7 yrs.	Under 14 yrs.	Over 14 yrs.	Total.	
1	Church of England	10	43	1	54	6,757
18	Ditto, under Inspection	2499	2634	13	5146	
2	Roman Catholic	318	456	2	776	1,040
4	Dissenting	160	232	10	402	8,557
5	Ditto, under Inspection	642	764	66	1472	
48	Private Schools, Academies, and Establishments not directly connected with any Place of Worship	489	1402	184	2075	
78		4118	5531	276	9925	16,354

SUMMARY.		
1861.	Day Scholars.	Sunday Scholars.
Manchester	31,923	42,687
Salford	9,925	16,354
	41,848	59,041

In a return prepared by the Rev. Dr. Turner and the Rev. Canon Toole, it was stated that accommodation was provided, in Roman Catholic Day-schools, in Manchester and Salford, for 6310 scholars, and in Sunday-schools for 8600 scholars.

Manchester Newspapers.—The average number printed weekly in 1840 was 22,000; in 1860, 438,700. The average weekly number of advertisements in 1840 was 970; in 1860, 8060.

In summarizing, Mr. Chadwick asked, Have our municipal regulations for preserving order, our sanitary regulations for preserving health, our social regulations for providing healthful means of physical and intellectual enjoyment, our educational regulations for providing instruction and the means of pursuing scientific inquiry, been such as could reasonably have been expected from a people so earnestly engaged in trade as the inhabitants of Manchester, and the manufacturing districts of Lancashire generally? And he concluded by expressing an opinion that, whether viewed in regard to material comforts, the means for obtaining education and intellectual advancement, the making provision against the occurrence of sickness, accident, or distress,—or in any way in which the general welfare of the great mass of the people can be estimated,—there has been a large and gratifying increase in the means placed at their disposal for improving their physical, moral, and intellectual well-being.

On a Revision of National Taxation. By Dr. W. Clarke.

Taking the income of the country, from all sources, at 642 millions sterling, which he divided into two schedules, in one of which he classed incomes from realized property, and in another profits from trades, professions, pensions, salaries, &c., he advocated a graduated scale of per-centage on these incomes, and the retention of the duties on articles of luxury.

On the Growth of the Human Body in Height and Weight in Males from 17 *to* 30 *Years of Age. By* J. T. Danson.

The author having observed that, at the Walton Jail, near Liverpool, a record was kept of the height and weight of the persons entering and leaving, and that within two years nearly five thousand persons (males) had been thus measured and weighed with much uniformity and accuracy, had the figures extracted from the books of the jail in order to apply the results to an examination of the data supplied on the above subject by M. Quetelet, in his work 'Sur l'Homme.'

The result is given in a series of tables. It leads to the inference that the number of persons measured and weighed by M. Quetelet was, in almost every instance, too small to afford trustworthy indications. It also affords some reason for supposing that, on the whole population of this country, a general scarcity of food has a permanent effect on the average height of the generation born in the same year. The paper is printed at length in the 'Journal of the Statistical Society of London.'

Observations on the Manufacture of the Human Hair, as an Article of Consumption and General Use. By WILLIAM DANSON.

The author submitted for inspection specimens of articles manufactured from the human hair—two shawls, cotton warp, and which appeared to be of a very massive and heavy texture, and showed that was capable of being made into the finest fabrics for ladies, like the alpaca. In consequence of the above, the author received a communication from Leipsic stating that one firm is regularly consuming 12,000 lbs. annually of human hair in manufactured goods. It would appear fabulous to say that 100,000 or 200,000 bales might be obtained; perhaps 500,000 or a million could be obtained even within twenty-one years, that is, annually, and of all sorts, both long and short, and all of which is at present wasted and not enumerated in the articles of commerce or of general consumption.

The Aid now granted by the State towards the instruction of the Industrial Classes in Elementary Science—its Nature and Results. By Capt. DONNELLY, *R.E., Inspector for Science of the Science and Art Department.*

The Science Division of the Science and Art Department is constituted to encourage the teaching of science throughout the United Kingdom.

The branches of science thus aided are divided into seven heads or subjects, and each of these into two subdivisions, except the first, which is divided into three subdivisions.

I. Practical Plane and Descriptive Geometry, with Mechanical and Machine-Drawing and Building-Construction, or Naval Architecture.
II. Mechanical Physics.
III. Experimental Physics.
IV. Chemistry.
V. Geology and Mineralogy.
VI. Animal Physiology and Zoology.
VII. Vegetable Physiology, Economic and Systematic Botany.

Assistance towards instruction in these sciences is afforded in four different forms, viz.:—

A. Allowances to teachers on their certificates.

B. Public examinations, in which Queen's medals and prizes are awarded to all successful candidates, whether taught by a certificated teacher or not, held at all places complying with certain conditions. On the results of these examinations certificate allowances and payment on results are made to the teachers.

C. Payments on prizes to certificated teachers.

D. Grants towards the purchase of apparatus, &c.

1. *Certificate allowances to certificated teachers.*

In November of each year the Department of Science and Art holds an examination at South Kensington in all the above-mentioned subjects. Any one may attend this examination without payment of fees by sending in his name to the Secretary, Science and Art Department, in September, and may take up any one or more of the subjects or subdivisions at one time.

Certificates of three grades are given for success in these examinations, entitling the holder to the following scale of payments:—

For a first-grade certificate in any subject	£20
Second	15
Third	10

At the first examination for teachers in November 1859, shortly after the publication of the first minute, 57 candidates came up, of whom 43 were successful, taking 65 subdivisional certificates. The next year, 1860, 89 candidates came up; 75 were successful, and 121 subdivisional certificates taken.

If the successful candidate holds an Education-Department certificate, he is paid on that also in addition to the certificate of the Science and Art Department. The teacher obtains the certificate payments in the following manner:—The classes are examined once a year (see below, Public Examinations); and then for every pupil of the artisan class who *passes* such an examination as will qualify the examiner in reporting that his instruction has been sound, and that he has benefited by it, the teacher receives £4 of his certificate allowance. The artisan class is broadly defined as including all who are in the receipt of weekly wages, and their children. A pupil on account of whom payment is claimed must have received forty lessons at least from the teacher since the last examination at which payments were claimed on his account.

A committee must be formed of at least five well-known persons in the neighbourhood, who have to give the necessary vouchers that certain conditions have been strictly complied with. Thus, then, for a teacher to obtain the full benefit of his certificates, including those from the Education Department, at least a quarter as many students of the industrial classes must pass at the May examination (see fourth head of inquiry), in one or more subdivisions, as his certificate allowances amount to pounds; if more pass, he receives no more payment under this head, but if less, then for every one under, £4 less.

2. *Public examinations.*

In order to test the efficiency of the instruction, on the proof of which alone the payments are made to the teacher, an annual examination is held in May simultaneously all over the kingdom, an evening being fixed for the examination in each subdivision of the seven subjects.

It is conducted by the committee previously mentioned, to whom the examination-papers for the pupils in each particular subdivision are sent.

The results of these examinations are classified by the professional examiners of the department under three heads, in lists which are published.

1. All those who have *passed* in each subdivision of a subject,—the standard of attainment required being low, and only such as will justify the examiner in reporting that the instruction has been sound, and that the students have benefited by it.

2. From among those who *passed*, those who attained a degree of proficiency qualifying them for the 1st, 2nd, or 3rd-class Queen's prize.

3. The six most successful candidates in each subject throughout the United Kingdom, if the degree of proficiency attained be sufficiently high to warrant their being recommended for Queen's medals.

The Queen's prizes consist of books to be chosen by the candidates from lists furnished for that purpose, and are unlimited in number.

The Queen's medals are—one gold, two silver, and three bronze, in each subject for competition, throughout the United Kingdom.

At the last examination in May there were just 1000 papers, and of these 725 were *passed*, and would qualify the teacher for payment if they were of the industrial classes and had received forty lessons; 310 of these received Queen's prizes, 59 1st-class, 100 2nd-class, and 151 3rd-class, while 4 gold, 21 silver, and 16 bronze medals were awarded.

Although payments to the teacher are made only on pupils of the industrial classes, others are not excluded from examination. Any person may present himself or herself, but the local committee is permitted to charge a fee not exceeding 2*s.* 6*d.* to cover the expense of gas, &c. Such candidates are eligible to receive Queen's prizes.

3. *Payments on prizes to certificated teachers.*

Besides the above payment on certificates to the teachers, there are other payments which are not limited in amount, as in the case of the certificate allowances.

For every pupil of the industrial classes who obtains a Queen's prize, the teacher, if he is certificated and has given the pupil 40 lessons, receives a payment—£3 if the pupil obtain a first-grade Queen's prize, £2 if a second, and £1 if a third.

This amount is not limited; and at the last May examination many teachers obtained £30 and £40, from this source, in addition to their certificate allowance.

4. *Grants towards the purchase of apparatus.*

A grant of 50 per cent. on the cost of apparatus, diagrams, &c. necessary for the instruction of the class is made. These grants are limited to £10 to schools taught by a master who is not certificated.

The above payments on account of science-teaching are made by the Science and Art Department, and, I. are only made when the holder is employed in teaching a school or class not under inspection by the Education Department, but in connexion with the Science and Art Department; and the lessons must be given in Mechanics' Institutes and other places not receiving grants from the Education Department.

II. The teacher must give instruction in a day or evening school or class for the industrial classes, adults or boys, approved by the Science and Art Department, and open at any time to the visit and inspection of its officers. Any teacher employed in a day school under inspection of the Education Department must first have obtained the permission of that department to teach in such school or class.

III. The certificated master of an elementary school who has pupil teachers apprenticed to him cannot receive the science-certificate allowance even if holding a science certificate.

Certificated teachers of elementary schools who have not pupil teachers apprenticed to them have their time out of school-hours at their own disposal, so far as official regulations are concerned, and may, if further certificated in science, give scientific instruction under the Science and Art Department.

On the Recent Improvements in the Health of the British Army. *By* Dr. W. Farr.

The defects of the health of the Army, which had been before manifest in the figures of returns, struck every heart when they appeared in the thinned ranks before Sebastopol, in the sick-freighted ships on the Black Sea, and in the hospitals of Scutari. Mr. Sidney Herbert, from his position, felt the defects perhaps more acutely than any, and since that time, neglecting the ease and enjoyment which a splendid fortune placed at his command, he devoted himself to the sanitary reform of the Army, first in a Royal Commission, then in commissions for carrying out its recommendations, and lastly as Secretary of State for War in Lord Palmerston's Administration. Notwithstanding the heavy duties of that office, he continued to act on a Royal Commission, of which Lord Stanley is the chairman; and some of his last recorded words were inquiries into the means of saving the numbers of soldiers who are destroyed in hundreds every year by the bad sanitary arrangements rather than by the climate of India. His frank and winning manner, his knowledge of his subject, and his eloquence enabled him to overcome many obstacles; and he had some courageous colleagues, among whom he (Dr. Farr) must name as the foremost Florence Nightingale. Happily, before his death Lord Herbert witnessed some of the results of his measures: he saw the marvellous success of the China expedition; and he received the first annual report of the Director General of the medical department of the army, showing "a remarkable reduction in the mortality of all classes of troops." Lord Herbert was not satisfied with pointing out evils in a report. He got Commissions of practical men nominated by Lord Panmure, placing himself at their head, to remedy those evils. The labours of one of these Commissions were described in a recent Report by Dr. Sutherland, Dr. Burnett, and Captain Galton; and its measures for improving the sanitary condition of barracks and hospitals were so well conceived that they deserved to be studied by all who took an interest in the health of armies. The Sanitary Report of Dr. Logan and the Medical Report of Dr. Mapleton, with the accompanying papers, proved that sanitary and medical science had much to expect from medical officers. The Commission for carrying out improvements in the vital statistics of the Army laid down an elaborate and yet simple plan for the observation, record, and analysis of sickness, diseases, and casualties of the Army under various circumstances at home and abroad, in peace and in war. That plan was now in operation. He trusted the remarkable weekly reports would soon be promulgated, showing, as they did, very marked contrasts in different regiments. Having quoted returns to show that a manifest diminution had taken place in the mortality and sickness of the army, Dr. Farr continued by saying that, upon examination, it had been found that the great causes of the excess of deaths in the army were completely under control in all ordinary circumstances; and as they varied, their effects varied. If the measures that had been begun were completed, there was no doubt of the result; and if the causes of disease were studied under the new system of observation established by Lord Herbert, improved means of guarding the mechanism of the human frame would be discovered, and would accumulate year by year. As instances of the remarkable improvement in the health of the army in the United Kingdom, it may be mentioned that, while the annual number of deaths to 1000 of strength during the years 1837–46 was, in Infantry regiments, 17·9, in the Foot Guards 20·4, in the Royal Artillery 13·9, and in Dragoon regiments 13·6, the mortality fell in the year 1859 to 7·6 in Infantry regiments, to 9·1 in the Foot Guards, to 8·0 in the Royal Artillery, and to 8·0 in Dragoon regiments.

On Sanitary Improvements. By Mrs. Fison.

On the General Results of the Census of the United Kingdom in 1861*. *By* James T. Hammick, *F.S.S., Assistant Commissioner of the Census in England.*

The author commenced by describing the machinery which had been used for collecting the census in England, Scotland, and Ireland, and the Channel Islands. In England, 30,862 enumerators were employed; in Scotland, 8075; in Ireland, 5096 men of the constabulary force, 15 of the Coast Guard, and 173 of the Dublin constabulary; and in the Channel Islands, 50 superintendents were employed, and under them 260 enumerators. In the United Kingdom, including the superintending officers, there were altogether 48,730 local agents. In this number was not included the Custom-House officers and others employed to enumerate persons in vessels. The proportion of enumerators to the population was much larger in Scotland than in the rest of the country. In England the average number of persons to each enumerator was 655; in Ireland, 1091; while in Scotland it was 379. To this army of local officers, minute printed instructions and and blank schedules for distribution at every house were furnished from the central office. From the London office alone the printed papers forwarded before the census-day, by post and railway, weighed about 45 tons, which was equal to 4200 reams of ordinary foolscap paper. In Ireland, besides the usual information as to the number of houses and persons, the heads of inquiry included the educational status of the people, their religious profession, the number and causes of death, and other details connected with vital statistics. These last items would have been a needless addition to the census, were not Ireland still the only part of civilized Europe not possessing—and, judging from the proceedings of last session, not soon likely to possess—a system of registration of births, deaths, and marriages. Fortunately the tranquil state of the country allowed the men of the constabulary to be spared to carry out these large investigations; and they undoubtedly possessed peculiar qualifications for the task entrusted to them. The want of uniformity between the returns made from Ireland and other parts of the United Kingdom was a drawback to the general utility of the census in some respects; but all classes had readily joined in affording the fullest information. In this country no motive existed for concealment or falsification of the numbers of the people. There was no suspicion of the returns being used against the public in reference to taxation or military service, as was the case in several of the continental states. The number of persons residing in the British islands on the 8th of April last was 29,058,888. The men in the army, navy, and merchant service out of the country, either abroad or afloat, amounted to 275,900. The total popu-

* The figures cited in this paper, with respect to the population of the United Kingdom in 1861, were derived from the preliminary abstracts presented to Parliament, but stated to be only approximately correct, and still subject to final check and revision. Since the Meeting at Manchester, the revised numbers for England and Scotland have been published; those for Ireland, however, have not yet been declared. The population of England and Wales, according to the Census returns of 1861, is 20,066,224; of Scotland, 3,062,294.

lation, therefore, of the United Kingdom, including the Channel Islands and the Isle of Man, might be set down at 29,334,788. The male population of the United Kingdom, including the absent soldiers and sailors, was 14,380,634; the female population was 14,954,154; the females, therefore, exceeded the males by 573,520. To every 100 males there were 104 females. The disproportion of the sexes in this country, no doubt, existed long before it was made apparent by the census of 1801, and of late years it had evidently been increasing. It was well known that, in England, of children born alive 105 boys were born to 100 girls; and the proportion was nearly the same in Scotland and France. The males continued in excess of the females until the seventeenth year, when the number of the two sexes was nearly equal; at subsequent ages the females were always in excess of the males,—the change in the proportion being doubtless mainly due to a difference in degree of the dangers to which the sexes were exposed, to emigration, and to a lower rate of mortality amongst females. The gross population of the United Kingdom in 1801—taking an estimate for Ireland and the islands in the British seas, not then enumerated—might be set down at 16,095,000. In sixty years, an addition of more than 13¼ millions had been made to the inhabitants of the country, besides the vast numbers who had left to found and people new colonies in Australia, or crossed the Atlantic to settle in the United States or the colonies of America. For the whole period of sixty years, the numbers showed a rate of increase amounting to 82 per cent., or on an average 1·01 per cent. annually. During the first half of the period (1801–31) the rate of increase was more than twice as rapid as in the second half (1831–61). There was little emigration in the first thirty years; whilst the returns of the Emigration Commissioners furnished an account of nearly five millions of emigrants who sailed in the second period. The great seats of manufacturing and mining industry had maintained their rate of increase. This had especially been the case in the group of districts having Manchester for a centre, which had increased to the extent of 274,000 persons since 1851. A vast increase had also taken place in the localities having their centres in Birmingham (187,000); Newcastle (158,000); and Liverpool (106,000). London had increased 440,000, and now contained a population which would soon reach 3,000,000. On the other hand, a decreasing population had generally been shown by the returns from the agricultural districts; but how far this might be traced to special circumstances, such as the diminution of employment consequent upon improved methods of cultivation, and the substitution of the breeding of stock for tillage, and how far to other causes inducing the unskilled labourer to migrate from the country to towns, might form a profitable subject of investigation. An increase of population usually implied increased happiness; but the converse was not equally true; for the inhabitants might decrease without necessarily suffering privation and misery. Great anxiety had been felt on the subject of the result of the inquiry into the religious denominations, which, for the first time, formed part of the decennial census in Ireland. In obtaining these returns the enumerators met with every facility from the clergy and people; and, as only 15 complaints had been made about them, the Commissioners inferred that they were nearly correct. The following were the results in round numbers:—Roman Catholics, 4,512,000, or 78 per cent. of the whole; members of the Established Church, 682,000, or 12 per cent.; Presbyterians, 588,400, or 10 per cent.; all other persuasions, 8740: the Jews were only 322. The religious persuasions of the army and navy not having been distinguished, they were here distributed in proportionate numbers under the several denominations. The total number of Protestants in Ireland was 1,280,000, giving the Roman Catholics a majority of 3,232,000, or about 3·5 Roman Catholics to one Protestant. Even in "Protestant Ulster" there was a Roman Catholic majority of 17,000. A comparison of these numbers with the results of a special census of religious professions taken in 1834 showed that during the generation that had passed since that inquiry, while the population of Ireland had diminished by 2,190,000, the Roman Catholics had diminished by 1,945,000, the numbers of the Established Church (with the Methodists) by 130,000, the Presbyterians and other Protestants by 115,000. A new era had happily dawned for Ireland, although clouds still obscured her horizon. Evidences of the increasing material prosperity of the country were not wanting; and it might confidently be anticipated that the census of 1871 would show by figures the effects of social changes now in progress. The islands in the British seas and the Isle of Man had a population of 143,447, or 321 more than in 1851. These islands, having been resorted to from motives of economy by persons possessing small independent incomes, increased in population at the rate of 18 per cent. between 1831 and 841, and 15 per cent. in the following decade; but free-trade measures having deprived them of their special advantages, the numbers had remained stationary since 1851. According to the latest returns and official estimates, the population of the North American colonies was not less than 3,795,000, and that of the Australian group was 1,272,000. For the West Indies might be set down 990,000 on the authority of the well-known blue books. The Cape and other African Colonies contained 870,000 inhabitants; Ceylon, 1,754,000; Mauritius, Hong Kong, &c., 280,000. In Europe, Malta, Gibraltar, and Heligoland contained about 304,000. To these an enormous addition must be made for British India, stated by Mr. Hornidge, of the India Office, to contain (exclusive of the native and foreign states) not less than 135,442,000 souls. Add the population of the United Kingdom, and the result was what might truly be called a "grand total" of 274,000,000 of subjects of Queen Victoria. With regard to the mother country, increased intelligence, combined with the new discoveries of science, and the powerful inventions in aid of industry which had sprung up on every side, and, far above all other causes, the benefits conferred by the steam-engine, the railway, and free-trade, left no doubt that the material prosperity of Great Britain, and consequently the number of her people, would continue to increase.

On the Inspection of Endowed Educational Institutions. *By* J. Heywood, *F.R.S.*

The author stated that the Royal Commissioners, in their recent Report on Popular Education, had laid down the following important principle with reference to endowed educational institutions:—"That the power to create permanent institutions is granted, and can be granted, only on the condition implied, if not declared, that they be subject to such modification as every succeeding generation of men shall find requisite." This principle has been acted on ever since the Reformation, but it has never been distinctly expressed. Acting on this principle, and adopting as a basis the suggestions of Mr. Cumin, an assistant commissioner under the Royal Commission, the following recommendations had been prepared:—"That one of the Charity Commissioners should be an Education Commissioner, appointed specifically for that subject. That the Charity Commission should be brought into connexion with the system of the Committee of Privy Council on Education. That inquiries into endowed educational institutions, under the Charity Commission, should be conducted, as they are at present, by Government Inspectors. That no new education scheme should be passed by the Charity Commissioners until it had obtained the sanction of the Vice-president of the Committee of Council of Education, who is always a member of the House of Commons. That ordinances of the Charity Commission for the improvement of educational charities and for the conversion to the purposes of education, wholly or in part, of charities which are mischievous or useless as at present applied, be laid before parliament in the schedule of a bill, similar in form to inclosure bills." The author then instanced several examples of the want of local power to carry out desirable changes in the case of charities and endowed schools, including the Manchester Free Grammar School (income £3000), the Leeds Grammar School, the "Blanket" Charities of Manchester, &c. He said, it would be better that some small payment should in general be made by the parents for their children's education. According to the authority of Mr. Cumin the assistant commissioner, demoralizing results had accrued from the distribution of such charities as Clarke and Marshall's Charity in Manchester. Fictitious names had been used; relations had recommended other relations; some of the recipients were drunkards and bad characters, whilst others were receiving considerable wages. He fully agreed with the commissioner, that no one having children should be able to share in such doles, unless they sent their children to school. Passing from Manchester, he showed that the malversation of sums left in endowments was pretty general throughout the country, instancing (on the authority of Mr. Fearon) the case of an important school in the Eastern Counties, in which, there being no demand for Latin or Greek, and the master selected being determined to teach nothing else, he continued to receive his salary, though no scholars came, and the building fell into ruins. Masters of endowed grammar schools were commonly not prepared to teach anything beyond the classics and mathematics. Persons intimately connected with general educational pursuits should be enrolled amongst the Charity Commissioners. In the Leeds Grammar School, the Rev. Dr. Hook had the influence to obtain an enlargement of the plan so as to modify the erroneous legal decisions with respect to the limitation of grammar school instruction to Latin and Greek. The Royal Commissioners had recommended that the Charity Commissioners should merge into the Committee of Council on Education. At present the Charity Commissioners had not sufficient independent power to act. It had been found that a proposed change for the better in Coventry had provoked an opposition; and it was relinquished because it indirectly influenced the return of members of parliament. The general principle laid down by Mr. Cumin was, to do the best they could for their own day, instead of strictly following the will of the founders. The Charity Commissioners resided in London, and had accounts presented before them comprising fully two millions of money. They received an enormous amount of documents, which required arrangement and classification.

On the Condition of National Schools in Liverpool as compared with the Population, 1861. *By the* Rev. A. Hume, *LL.D.*

In 1853 a paper was read at Hull, before this Section of the Association, on the same general subject, and by the same writer. The present one brings down the facts and principles to the present time. The records which have been preserved at the Blue-Coat Hospital enable us to compare the progress of schools and of education with that of the population. The following are all Church schools:—

Decennial census.	Population of Borough.	Children in public schools.	
1821	131,075	2,478	1·89 per cent.
1831	205,572	3,099	1·51 „
1841	286,487	9,099	3·18 „
1851	376,065	16,106	4·28 „
1861	443,874	20,090	4·52 „

The order and rapidity of their foundation may be seen from the following table, which includes the Blue-Coat Hospital and the Industrial and Workhouse schools:—

1821,	in existence	9 schools.
1831,	„	15 „
1841,	„	30 „
1851,	„	43 „
1861,	„	50 „

In the earlier years of this period, schools were erected for the use of an entire neighbourhood or section of the town; afterwards national feelings, as distinguished from imperial ones, preponderated; so that separate schools were erected for the Scotch, Irish, and Welsh. In our own days, however, the population is so large that it is classified not only by religious denominations, but by congregations; so that every church and many chapels are regarded as incomplete without the possession of means of education.

During the summer and autumn of 1861, the state of 45 Church schools within the borough was as follows:—

Accommodation	Boys	8355	
	Girls	7715	
	Infants	6853	
			22,923.
On the books	Boys	7100	
	Girls	6683	
	Infants	7638	
			21,421.
Attendance	Boys	5673	
	Girls	5234	
	Infants	5976	
			16,883.

If we add 30 per cent. for those who are not regularly at school nor retained on the books, but who still come and go, and thus get an irregular education, we have 21,947 who may be said to be under education in these schools. If we increase, at the same time, the numbers which were reached in 1853 for schools of all other kinds (non-sectarian schools, and those patronized by Roman Catholics and Protestant Dissenters), we have 18,359 additional pupils. This gives us a total under education of 40,306.

In the Church schools there are 419 teachers of all kinds, or one for every 52 pupils. Only 83 are certificated, and many of the others are pupil teachers in their earliest years.

The gross number requiring education in the national schools of Liverpool has been computed at 73,979, of whom it appears that only 54 per cent. are formally (though sometimes imperfectly) educated. The remaining 46 per cent. comprise several classes, *e. g.* those who attend ragged- and Sunday-schools only, those who receive knowledge like food, irregularly and insufficiently, and those who receive the practical education of vice and immorality.

The sites of the schools are particularly deserving of consideration; and we are fortunately enabled to examine the facts minutely, in connexion with the recent census of the borough, returned in ecclesiastical districts.

	Population.	Accommodation, Church schools.	Per-centage of pupils.
(*a.*) Western or poor portion	195,401	9336	4·78
(*b.*) Middle portion	162,361	7830	4·82
(*c.*) Selected parts, richest	75,896	5470	7·27

These figures do not show the full extent of the unequal distribution of education, because in the first portion nearly all the children should attend schools of this class; while in the third, where the rich reside mainly, education should be almost entirely self-supporting. In four of the best ecclesiastical districts the population is 22,486, yet there are 2421 children educated, or 10·77 per cent. In one district, St. Saviour's, the per-centage rises to 17·25. In six poor districts there is a joint population of 99,361, and the Church educates in like manner 1822, or 1·83 per cent. In four other districts, the population of which amount to 33,208, there are no national schools.

The cost of educating these 21,947 is to the town about £10,956 per annum; and the distribution of the amount is as follows:—donations and subscriptions 28 per cent., church collections 10, children's pence 44, and all other sources 18. This, of course, is independent of the interest of money expended in land and buildings, and includes none of the Government annual payments, except capitation fees. The average is nearly 10*s.* per head; but the largest portion is paid to the rich districts, where it is least required, and the smallest portion to the poor districts, which most need it. The children's payments are usually 1½*d.* and 2*d.*; but in two or three schools they rise to 6*d.*, in six others to 4*d.*, and in four or five more to 3*d.* In some of the schools in the lower parts of the town the children can pay nothing whatever; and at one district-school it is found necessary to educate about 50 per cent. free.

Hence it follows that the district or parochial system is good, but is badly applied. Men subscribe to the rich community in which they live, and withhold aid from the poor one in which they work and accumulate property. If the necessities of one be five times as great as those of another, while at the same time pecuniary aid is obtained with only one-fifth the facility, the task of educating the people at one part will be twenty-five times as great as at another. The Committee of Council interpret the word "parish" as meaning in towns a circle of five miles' radius; but practically it refers to a much narrower limit.

The Liverpool Church of England School Society supports three sets of schools entirely, and votes small sums as a rate in aid to others.

3 schools, with 1100 pupils, receive £500 a year.
10 „ „ 2529 „ „ £145 (£10 to £25 each).

If the number of schools assisted were extended and the amount of aid increased, the evils arising from the coexistence of riches and poverty in the same town would be greatly modified.

The Committee of Council in London know nothing of the grades of population at particular points, but are continually misled by the ambiguous term "poor." A local committee, administering funds raised by local subscriptions or local rates, can alone remedy some of these evils; and it is a great misfortune that either the apathy of some men or the disagreement of others has hitherto, in a great degree, prevented us from arriving at a degree of perfection within easy means of attainment.

On the True Principles of Taxation. *By* C. E. Macqueen.

The paper consisted of a comparison of the diverse character of direct and indirect taxation; and its object was to show that the action of the latter was always injurious, and that direct taxation was the only one consistent with sound financial principles. Of various schemes of direct taxation, three were mentioned as most deserving of attention, although the Financial Reform Association did not commit itself to their advocacy. The first of these plans was the Land Tax of William III. according to its original intent, with a small capitation tax in addition, as suggested by the author of the 'People's Blue Book;' the second the American system, taxing only real property and personal estate above the value of £50; and the third, the plan recommended in the draft report of the late Joseph Hume to the Income Tax Commissioners of 1852, based on capitalizing all incomes,—a scheme supported by Dr. Farr and others.

On the Progress of Cooperation at Rochdale. *By the* Rev. W. N. Molesworth, *M.A.*

The rapid progress and diffusion of cooperation is effecting a great change in the condition of the working class, and in its relations with every other class. It has therefore naturally excited much interest and attention. What has been done in Rochdale may be done elsewhere; the experience which has been gained there may serve to guide and encourage societies which are in an earlier stage of their progress, and may enable us to form some sort of rough estimate of the proportions that cooperation may be expected to assume hereafter. A careful examination of a single case will be the best preparation for forming a sound judgment respecting the whole movement.

The first thing that seems to be requisite is to give some sort of definition of the principle which is embodied in these societies; and I cannot do this better than by copying their own statement of their objects.

"The objects of this society are the social and intellectual advancement of its members; it provides them with groceries, butcher's meat, drapery goods, clothing, shoes, clogs, &c. There are competent workmen on the premises, to do the work of the members, and execute all repairs. The capital is raised in £1 shares,—each member being allowed to take not less than five, and not more than one hundred, payable at once or by instalments of three shillings and threepence per quarter. The profits are divided quarterly as follows:—1st. Interest at 5 per cent. per annum, on all paid-up shares; 2nd. 2½ per cent. off net profits for educational purposes, the remainder divided amongst the members in proportion to money expended. For the intellectual improvement of the members, there is a library consisting of more than 3000 volumes. The librarian is in attendance every Wednesday and Saturday evening, from seven to half-past eight o'clock. The news-room is well supplied with newspapers and periodicals, fitted up in a neat and careful manner, and furnished with maps, globes, microscope, telescope, &c. The news-room and library are free to all members. A branch reading-room has been opened at Oldham-road, the readers of which meet every second Monday in January, April, July, and October, to choose and sell the papers."

This statement is given at full length: though there are some portions of it which may seem not quite relevant to our purpose, yet it contains nothing which does not throw some light on the spirit in which the society has been conceived and carried on. In sciences which have been carried to a high pitch of perfection, such as astronomy and the physical sciences, accuracy of definition is indispensable; but in the less advanced and more complex questions of social science we cannot define with the same degree of strictness, and it is much better to make our boundaries include too much than to render them too narrow.

It may provoke a smile to find, in the above-cited statement of objects, "social and intellectual advancement" placed side by side with "groceries, butcher's meat, drapery goods, clothing, shoes, and clogs." Yet this juxtaposition indicates a confused sense of a very important truth, and one that gives to cooperation a far higher value than seems at first sight to belong to it, namely, that the material or financial progress is the basis and the measure of the intellectual and moral progress: for increased wealth implies an increased command over the necessaries of life; it therefore implies more leisure; and though this leisure may sometimes be abused, it will, as a general rule, be rightly used, and especially by men who have purchased it by industry and self-control. There have, no doubt, been cases in which increased wealth has been attended with the most frightful moral dissolution and intellectual decay; but this has arisen not from the wealth, but from the excessive inequality of its distribution. But when the wealth of a society is equitably distributed through the various classes that compose it—when it is allowed, in fact, to take its natural and normal course, then the material progress becomes the instrument and the condition of every other kind of progress. When, therefore, we trace, as I shall now proceed to do, the financial history of the Rochdale Co-operative Society, we are roughly indicating, be it remembered, the general intellectual and moral progress of its members, of which, as I said before, the material development is the measure.

In the year 1843, when the "Rochdale Equitable Pioneers' Co-operative Store" commenced, the New Poor Law had prevented the operatives of Rochdale from regarding parochial relief as a source on which they might always rely in case of loss of work, and of those periodical crises to which our manufacturing system has always been liable. The recent failure of the Rochdale Savings' Bank, which had been plundered to a fearful extent by its accountant, had destroyed all faith in that popular institution; and the Rochdale operatives, who looked beyond the present moment, seemed to have no alternative but that of hiding their little savings in an old stocking, to be brought out of its place of concealment when the day of distress arrived. It was under these circumstances that twenty-eight Rochdale operatives contributed a sovereign each, for the purpose of establishing a shop, at which they might purchase genuine groceries and other articles of ordinary consumption at a moderate rate. It was an experiment which had often been tried before on a larger scale, and apparently under more favourable auspices; but, from the causes we have mentioned, the condition of the Rochdale operatives was desperate, and, like brave men, they determined not to succumb, but to make another effort and hope for better days.

The following Table, taken from their Almanack for the year 1861, gives a very good view of the operations of the Rochdale Society from its commencement to the close of last year:—

Operations of the Rochdale Equitable Pioneers' Co-operative Society, from 1844 to 1860.

	No. of Memb.	Amount of Funds.			Business done.			Profits made.		
		£	s.	d.	£	s.	d.	£	s.	d.
1844	28	28	0	0						
1845	74	181	12	5	710	6	5	32	17	6
1846	80	252	7	1½	1,146	17	1	80	16	6
1847	110	286	15	3½	1,924	13	10	72	2	10
1848	140	397	0	0	2,276	6	5½	117	16	10½
1849	390	1,193	19	1	6,611	18	0	561	3	9
1850	600	2,299	10	5	13,179	17	0	889	12	5
1851	630	2,785	0	1½	17,638	4	0	990	19	8½
1852	680	3,471	0	6	16,352	5	0	1,206	15	2½
1853	720	5,848	3	11	22,760	0	0	1,674	18	11½
1854	900	7,172	15	7	33,364	0	0	1,763	11	2½
1855	1400	11,032	12	10½	44,902	12	0	3,106	8	4
1856	1600	12,920	13	1½	63,197	10	0	3,921	13	1½
1857	1850	15,142	1	2	79,788	0	0	5,470	6	8½
1858	1950	18,160	5	4	71,689	0	0	6,284	17	4½
1859	2703	27,060	14	2	104,012	0	0	10,739	16	6½
1860	3450	37,710	9	0	152,083	0	0	15,906	9	11

After the society had been carried on for seven years, it was found that more capital was offered to be invested than could be profitably employed in the store. At the same time there were great complaints of the quality of the flour sold in the shops, which was supposed in many cases to be greatly adulterated. In fact, there was at the time a very strong feeling on the subject of adulteration everywhere; and this feeling very naturally applied to flour, as a chief constituent of food, more than to any other article. The consequence was that in the year 1850 a Co-operative Corn-Mill Society was established, for which a substantial mill was built in Weir-street, Rochdale, the financial progress of which is exhibited in the following table:—

Financial Statistics of the Rochdale District Corn-Mill Society, from 1850 to 1860.

Date.	Amount of Funds.	Business done.	Profits made.
	£ s. d.	£	£ s. d.
1850		None.	
1851	2,163 16 4	*	† None.
1852	2,898 0 4	7,036	336 16 8
1853	4,143 19 4	16,679	208 15 11½
1854	3,671 17 0	22,047	557 12 10
1855	4,626 2 9	28,085	1,376 9 4
1856	8,784 4 9½	38,070	773 10 9½
1857	10,601 14 2½	54,326	2,007 1 5
1858	14,181 9 10	59,188	3,153 14 0½
1859	18,236 0 0	85,845	6,115 0 9
1860	26,618 14 6	133,125	10,164 12 5

The success which attended the operations of these two societies produced great confidence, and was followed by a desire on the part of the operative class to invest their savings in them, and this soon produced the necessity of finding another investment for their capital. Accordingly, in the year 1854, a Manufacturing Society was formed on the same general principles as the Store and the Corn-Mill Society, and has been attended with similar success. At first they hired buildings in which the manufactures were carried on; but on the 22nd April, in the year 1859, they laid the first stone of a factory of their own, which was completed, I believe, without a penny being borrowed during the progress of the work (in fact, they always had a very large balance at the bank), and it is universally admitted to be one of the best and largest factories in the borough of Rochdale. Scarcely was this gigantic work finished, than they found themselves in a position to commence another factory alongside of it, which is now rapidly rising, and for the completion of which there is reason to believe that ample funds will be forthcoming.

But these great works, such has been the rapidity with which capital has been developed by the success of their operations, have not exhausted their resources. In the year 1860, while the great factory was still rising, a Sick and Burial Society and a Turkish Bath were established by some of the more active and energetic members of the Co-operative Society. And lastly, in the present year, a Land and Building Society has been established, and is already actively engaged in erecting commodious dwellings for the working class.

The capital of these various institutions at the present time is thus estimated:—

Co-operative Store	£39,335
Corn-Mill	29,962
Manufacturing Society	71,695
Land and Building Society	1,000
Turkish Bath	350
Total	142,342
Deduct loans from Store to other Societies ..	16,613
Leaving a net capital of..................	125,729

* Account mislaid. † 1851, Loss £421 7s. 9d.

This capital consists of actual money, or stock purchased by money, and which might very fairly be estimated at a value considerably above its cost price.

Now let us pause for a moment to consider the progress that has been made.

In the year	1844 the capital was	£28
„	1850, commencement of Corn-Mill	2,299
„	1854, commencement of Manuf. Soc.....	11,144
„	1861	125,729.

But this does not by any means represent the whole of the financial co-operative progress in Rochdale. Several other societies have come into existence, which, though independent of this Society, and not recognizing so clearly as this Society the principles of cooperation as laid down by it, are nevertheless societies which receive and develope the resources of the working-classes, which tend to raise them morally, socially, and intellectually, as well as materially, and which must not, therefore, be wholly left out of our account in estimating the progress which cooperation has made in Rochdale. It would be foreign to my present purpose to enter into an enumeration of their operations. I only refer to them in order that the Section may understand that the progress described in this paper is very far from representing the whole of the results of the principle of cooperation in the town of Rochdale.

There is one thing to which I would advert before I leave the subject, which is greatly to the credit of the principal promoters of this movement, and is all the more necessary to be mentioned, because the contrary is sometimes asserted. I cannot, of course, speak for all of them; but, as far as I have had an opportunity of observing them, I have been struck with the absence of that levelling spirit and of that desire of self-aggrandizement which has characterised some of the working-class attempts to elevate themselves. The chief ambition of the principal promoters of the movement in Rochdale appears to me to be to raise themselves by raising the class to which they belong, without desiring to leave it, and without the slightest wish to depress or injure any other class. Their object and their ambition appears to be that the working-class should be well fed, well clothed, well housed, well washed, well educated—in a word, that they should be respectable and respected. If any taint of the socialist and communist theories in which the society originated still cleaves to them, it is being rapidly worked off, and will, I am persuaded, shortly disappear. And, to their honour be it spoken, so far are they from trying to monopolize the advantages they have acquired, that they are animated by a generous spirit of proselytism, and put themselves to considerable trouble and expense in communicating to inquirers from all parts of the kingdom the results of their experience, and aiding them in the formation of new societies. The following extract from a paper they have printed for the use of persons wishing to form new societies will serve to illustrate this remark, and will I am sure, be listened to with interest by the Section:—

"1st. Procure the authority and protection of the law by enrolment.

"2nd. Let integrity, intelligence, and ability be indispensable qualifications in the choice of officers and managers, and not wealth or distinction.

"3rd. Let each member have only one vote, and make no distinction as regards the amount of wealth any member may contribute.

"4th. Let majorities rule in all matters of government.

"5th. Look well after the money matters. Punish fraud, when duly established, by the immediate expulsion of the defrauder.

"6th. Buy your goods as much as possible in the first markets; or, if you have the produce of your industry to sell, contrive, if possible, to sell in the last.

"7th. Never depart from the principle of buying and selling for READY MONEY.

"8th. Beware of long reckonings. Quarterly accounts are the best, and should be adopted when practicable.

"9th. For the sake of security, always have the accounted value of the 'Fixed Stock' at least one-fourth less than its marketable value.

"10th. Let members take care that the accounts are properly audited by men of their own choosing.

"11th. Let Committees of Management always have the authority of the members before taking any important or expensive step.

"12th. Do not court opposition or publicity, nor fear it when it comes.

"13th. Choose those only for your leaders whom you can trust, and then give them your confidence."

The principles by which the society whose progress has been described is distinguished from the numerous joint-stock societies established under the Limited Liability Act appear to me to be these:—

1. To make the material improvement of the working-class subservient to their social and intellectual advancement.

2. Neither to give nor take credit.

3. To keep the governing body under the constant and vigilant superintendence of a proprietary resident on the spot, and the greater part of whom are acquainted with the nature of the operations carried on with their capital. This is a cause of their success to which, I believe, attention has not yet been directed, but which is very important.

On these principles two questions arise—

1. Are they sound?

2. Are they applicable to manufacturing operations, as well as to stores for the sale of goods?

On these questions I do not profess to dogmatize. I see this institution established and carried on for sixteen years under my own eyes. I am naturally desirous to investigate its character; it is an inquiry of no small importance, and one which I think ought to receive the careful attention of this section.

On the Price of Printing Cloth and Upland Cotton from 1812 *to* 1860. *By* Alderman Neild.

By two tables (which are printed in detail) he showed the price of a description of cloth known as $\frac{7}{8}$-72-reed printers, in each year, from 1812 to 1860, by which is meant 72 threads of warp in the inch, and the best class of this description of cloth has 88 threads of weft in the same space. This description of cloth is now in part superseded by a $\frac{9}{8}$ cloth, which, assuming it to be of the same quality, will measure in the grey 25 yards long and 36 inches wide. Although the $\frac{7}{8}$ are giving place to $\frac{9}{8}$, the comparison in $\frac{7}{8}$ was continued throughout. The present difference in value between an 80-and a 72-reed will be about 9*d.* per piece. He mentioned a remarkable circumstance, showing the astonishing superiority of power-loom cloth over hand-loom. As buyers of cloth, they applied a very close scrutiny to every lot of cloth purchased, as to the warp, weft, length, breadth, and weight. The accuracy with which one piece compares with another in all these particulars, in the productions of first-class makers, was surprising—the item of weight, however, being the one in which the greatest difference is to be apprehended. But even in this, the difference the first makes in large quantities of cloth would not be more than about five ounces in cloth weighing 5 lb. 2 oz. (that is, taking a number of pieces, and weighing each piece singly); but taking the average of a number of lots of 20 pieces each, thus extending over thousands of pieces, they will not vary more than from 1 to 2 oz.; whilst, taking the case of the 80-reed cloth named in the first six years of this table, a variation was found in cloth purporting to be the same of from 5lb. 1 oz. to 6 lb. 4 oz. The two most remarkable years were 1814 and 1825. The first (1814) was soon after the Continent had been closed to our manufactures for probably 20 years, and when it was believed (to quote a saying of the time) "there would not be a piece for every village." The excitement became intense, and 80-reed grey printing-cloth rose from 25*s.* per piece to 49*s.*, and one style of prints rose from 44*s.* 4*d.* to 63*s.*, or from 19*d.* per yard to 2*s.* 3*d.* A much superior article of the same class is now sold for 11*s.*, or about $4\frac{5}{8}$*d.* per yard, so much better, both in design and execution, and brilliancy of colour, that, if the production of 1814 were placed side by side with the production of 1860 at two-thirds of the price, the price of 1860 would be taken, and the one of 1814 left. The year 1825 was one of extraordinary speculation and excitement, principally, if I remember rightly, in raw cotton. The manufacturer endeavoured to keep pace by advancing his cloth, and $\frac{7}{8}$-72-reed printing-cloth rose, in that year, from about 13*s.* 6*d.* to 19*s.* This, however, had the effect of almost putting a stop to the demand; and sales, except to a very limited extent, were out of the question. The result was, a great accumulation of stocks. The usury laws were then in force, and, in consequence of the very high rate of money, manufacturers were driven to most terrible sacrifices upon their stocks. At length, prices began to give way; and the cloth in question fell from 19*s.* to 13*s.* 6*d.*, and then to 10*s.*, or nearly 50 per cent. from the highest point. This fall occurred in a period of about nine months. In 1848, this same cloth touched the very low point of 4*s.* 6*d.*, its present value being 6*s.* 10*d.* In 1816 the price of 80-reed cloth was 29*s.*—a period of depression rather than excitement; whilst it fell in 1848 to 4*s.* 6*d.* Then, again, as another instance of the change in value, and looking at the column of average prices,

			COTTON.			
			Highest.		Lowest.	
	s.	*d.*	*s.*	*d.*	*s.*	*d.*
In 1818 it was....	21	9	1	10½	1	4½
1826 „	10	6	0	8¾	0	5¼
1837 „	7	9	0	10⅝	0	6
1846 „	5	6	0	6½	0	4¼
1848 „	4	9½	0	5	0	3¾

After this, prices began to advance, until, in 1860, they touched 7*s.* The causes which have operated to produce these changes are a reduction in the price of the raw material, improved machinery, improved training of the hands employed, and the enormous increase of demand, which have enabled the manufacturer to diminish the cost per piece on his fixed expenses by turning off a greater number of pieces from the same machinery. Lowness of price, again, has been continually stimulating the demand. He had thus shown the history of the fluctuations in the price of one article for a period of about half a century, forty-three years of which had been merely the record of his own purchases.

On the Extent to which Sound Principles of Taxation are embodied in the Legislation of the United Kingdom. By W. NEWMARCH.

H. J. KER PORTER presented Engravings of Farm Labourers' Cottages, with a Specification, and made a few remarks, in continuation of a Paper read at Oxford in 1860.

On Cooperation and its Tendencies. By EDMUND POTTER, *F.R.S.*

He pointed out, at starting, the danger of trying to elevate a simple and useful means of thrift into a presumed new mode for the scientific application of labour and capital. After fully discussing the subject, the conclusions he arrived at were thus stated:—1. The conclusion I should arrive at, drawn from the opinions I have expressed, would be, that cooperation is sound only when limited to simple and almost unspeculative trading, such as the division of stores, for supplying a provided demand from shareholders, or for institutions and establishments for limited purposes, such as would safely admit the democratic principle of management. 2. That it is inefficient for competitive and therefore speculative commercial undertakings, because it could not, through agents democratically elected and intrusted only with limited responsibility, compete with individual responsibility of greater power. 3. That it would prove weakest during periods of depression, and could not find power of sustentation from a multitude of shareholders of the weaker capitalist class: that it would not supply the power of purchase or expansion during those periods, when the private capitalist invests and expands most profitably. 4. That the more substantial capitalist would be debarred by socialistic rule, which limits the amount of shares to be held, from finding financial and moral support; therefore the pressure of adversity would come with infinitely greater weight on cooperative associations than on joint-stock or individual trades. 5. That cooperative experiments, though costly to their supporters, may be valuable to society by affording practical lessons in political economy, and testing the value of, and necessity for, forethought and experience; that the greater diffusion of education will not lead to cooperation for trading purposes, but to greater self-reliance and competition.

On the Relative Pauperism of England, Scotland, and Ireland, 1851–1860. *By* FREDERICK PURDY, *F.S.S., Principal of the Statistical Department, Poor Law Board.*

This paper treated of the relative pauperism of England, Scotland, and Ireland during the ten years ended in 1860. It pointed out that each country had its own Poor Laws, and its separate administrative machinery. Poor Laws had existed in England for nearly three centuries; but in Scotland there was nothing worthy of the name before 1845; and in Ireland they were introduced in 1838. In England the average number of paupers was 892,671; in Scotland, 120,724; in Ireland, 95,880; or 4·7, 4·0, and 1·5 per cent. on the population, respectively. It was stated that those who had devoted themselves to study the working of the English Poor Laws were opposed to the system of "out-door relief," from the difficulty of testing the applicant's claim, and from the fear that it may be perverted, in the hands of the employers of labour, who constitute the majority of the immediate administrators of relief, to the depression of wages. It appeared that for 1 in-door pauper in England there were 6 out-door; in Scotland, 13; but in Ireland ·03 only. Though pauperism is lowest in Ireland, it was shown that in Scotland, where nearly all the relief is *out-door*, the resident Irish were greatly pauperized, for 1 in 13 was there a pauper; but in Ireland only 1 in 274. According to the most recent statistics, there were 43,810 pauper lunatics in the United Kingdom,—England having 33,068, Scotland 5103, and Ireland 5639 of this unfortunate class. On each 10,000 of the population, England has 17, Scotland the same, and Ireland 9 only. The Commissioners, who in 1858 reported upon the Irish lunatic asylums, stated that there were 3350 "insane poor at large and unprovided for." This would, if they were to be included hereafter as paupers, raise the Irish ratio considerably. In the ten years £92,285,965 had been raised by poor-rates. In England, £77,960,190; Scotland, £6,182,526; and Ireland, £8,143,249. But of the English portion, £18,000,000 were for purposes quite unconnected with relief to the poor. The sums actually spent in relief to the poor were, for England, £54,767,542; Scotland, £5,917,634; and Ireland, £6,656,745, respectively equal to a rate per head on the population of 5*s.* 9½*d.*, 3*s.* 11¼*d.*, and 2*s.* 1¾*d.* annually. The proportion was nearly *triple* in England, and *double* in Scotland, that which sufficed for Ireland. Comparing the amount expended in 1860 with that of 1851, it appeared that in England it was now 10 per cent., and in Scotland 25 per cent. *higher*. In Ireland, on the other hand, it was now 60 per cent. *lower*. The yearly cost per pauper was, for England, £6 2*s.* 8*d.*; Scotland, £4 18*s.*; and Ireland, £6 18*s.* 10*d.* Ireland stands highest here, because relief in the workhouse is dearest *individually*, though in its ultimate effects the most economical and the least demoralizing. The comparison of the rate in the pound, on the property-tax assessment, was then made in respect of the seven years ending in 1860, there being no return for Ireland previous to 1854. The relief to the poor during that period was equal to an annual tax, on the Schedule A assessment, of 1*s.* 1*d.* in England, 11½*d.* in Scotland, and 10¾*d.* in Ireland. It was considered remarkable that, however diverse the pauperism of the three kingdoms had otherwise been, yet, in this relation, there was a considerable approach to uniformity—England only exceeding Scotland by 1½*d.* and Ireland by 2¼*d.* in the pound. The rate per head of the assessments under Schedules A, B, and D, on the average population of the seven years, was computed to show the relative wealth of the three countries: this in England was £11 17*s.*; in Scotland, £9 13*s.*; and in Ireland, £3 5*s.* Taking these in conjunction with previous ratios, it would appear that the pauperism has been *inversely* as the poverty of the three countries—England, the wealthiest and most pauperized; Ireland, the poorest and least pauperized; Scotland coming between, but much nearer to England, both in wealth and in pauperism. It was asked, in conclusion, If Ireland, under the judicious administration of her Poor Laws, has reduced her pauperism to a quantity which, at the present day, is less than *one per cent.* of the population, under what conditions can we hope that similar results may be achieved for England and Scotland? But it was observed that something beyond statistical information is required for the satisfactory solution of this important question.

Some of the more important data discussed in this paper are briefly exhibited in the subjoined Tables:—

A.—Yearly Average of the Pauper Census, 1851–1860.

	Number of Paupers.		
	In-door.	Out-door.	Total.
England and Wales	117,395	775,276	892,671
Scotland	—*	—*	120,724
Ireland	93,281	2,599	95,880
United Kingdom	—	—	1,109,275

B.—Yearly Average of Poor Rates raised, 1851–1860.

	Amounts raised		
	by Poor Rates.	by other receipts.	Total.
	£	£	
England and Wales	7,504,439	291,571	7,796,010†
Scotland	556,127	62,126	618,253
Ireland	778,617	35,708	814,325
United Kingdom	8,839,183	389,405	9,228,588

C.—Yearly Average Expenditure for Relief, 1851–1860.

	Population (average).	Relief to the Poor.	Rate per head.	Variations in the rate per head in 10 years.	
				highest.	lowest.
		£	s. d.	s. d.	s. d.
England and Wales	18,902,000	5,476,754	5 9½	6 3	5 4½
Scotland	3,009,000	591,763	3 11¼	4 2	3 7
Ireland	6,193,000	665,675	2 1¾	3 5¾	1 6½
United Kingdom	28,104,000	6,734,192	4 9½	5 1	4 5

NOTE.—Mr. Purdy's paper, with all the Tables, is printed *in extenso* in the 25th volume of the Journal of the Statistical Society.

The Iron-cased Ships of the British Navy.

By E. J. REED, *Member and Secretary of the Institution of Naval Architecture.*

The construction of iron-cased ships of war is engrossing so much of the attention of scientific men at the present moment, and is manifestly fraught with such important consequences in financial respects, that this Association could not well be expected to assemble, even in Manchester, without taking the subject into consideration.

With the view of best fulfilling the intentions with which the gentlemen of the Mechanical Section made this the chief topic of today's deliberations, I propose—

1st. To glance briefly at the circumstances under which the British Admiralty resorted to the construction of iron-cased sea-going ships of war.

* The numbers of indoor and outdoor paupers in Scotland appear only to have been separately stated once; that was in 1859, when they amounted to 8,678 and 113,335 respectively.

† In England and Wales large sums are paid yearly for local purposes, unconnected with relief to the poor; on the average, these payments have been £1,823,950.

2nd. To state as compactly as possible the principal features of the ships which the Admiralty are building and propose to build.

And 3rdly. To bring to the notice of this Association the great increase of dock accommodation which iron-cased ships have rendered necessary.

Early in 1859 the Secretary to the Admiralty, the Accountant-General of the Navy, and the Secretary and Chief Clerk to the Treasury, together reported to the Government of the day (Lord Derby's) that France was building "*four* iron-sided ships, of which two were more than half completed," and that these ships were to take the place of line-of-battle ships for the future. "So convinced do naval men seem to be in France of the irresistible qualities of these ships," said these gentlemen, "that they are of opinion that no more ships of the line will be laid down." In another part of their Report they said, "The present seems a state of transition, as regards naval architecture, inducing the French Government *to suspend the laying down of new ships of the line altogether*." At the instance of Sir John Pakington, then First Lord of the Admiralty, this Report was immediately presented to Parliament, and thus obtained universal publicity.

From that time forward, then, we have all known perfectly well what the plans of the French Government in this matter were, and have known equally well that the only mode of keeping pace even with France in the production of iron-cased ships was to lay down four of them to match the four which she at that time possessed, and to build as many more annually as she saw fit to add to her navy. In pursuance of this very simple policy, Sir John Pakington at once had designs of a formidable class of iron-cased ships prepared, and ordered the construction of one of these vessels, the 'Warrior.'

The present Board of Admiralty shortly afterwards succeeded to power, and ordered a second of these vessels, the 'Black Prince,' and after some delay also issued contracts for the 'Defence' and 'Resistance.' No other vessel of the kind was actually commenced until the present year; so that in the beginning of 1861 we had only just attained the position which France held in the beginning of 1859, having "*four* iron-sided ships, of which two were more than half completed." Meantime France had been devoting the bulk of her naval expenditure for two whole years to the production of similar vessels, and is consequently now in possession of an iron-cased fleet far more considerable and more forward than ours.

At length, however, our sluggishness has been overcome, and we have set ourselves earnestly to work to repair our past deficiencies. The 'Hector' and 'Valiant' have been laid down, and are being urged rapidly forward; the 'Achilles,' after a year's preparation, has been fairly commenced; the 'Royal Alfred,' the 'Royal Oak,' the 'Caledonia,' the 'Ocean,' and the 'Triumph' are in progress; and contracts have just been issued for the construction of three out of six other iron-cased ships, the building of which has for some time been decided upon. The peculiar features and proportions of these vessels I shall presently describe; but I will first state some of the causes which have led to delay in this matter, and set forth the circumstances under which we have at last been compelled to advance.

We have heard much in various quarters about the *invention* of iron-cased ships, the credit of which is usually accorded to his Imperial Majesty Napoleon III., although there are scores of persons, both here and in America, who claim it for themselves. But the truth is, very little invention has been displayed in the French iron-cased ships. Their designers have almost exclusively confined themselves to the very simple process of reducing a wooden line-of-battle ship to the height of a frigate, and replacing the weight thus removed by an iron casing 4½ inches thick placed upon the dwarfed vessel. It was not possible to produce a very efficient ship by these means; so they have contented themselves, in most cases, with vessels like 'La Gloire,' which carry their ports very near to the water when fully equipped for sea, and are characterized by other imperfections that it would be easy to point out. The reports of her efficiency which have appeared in the French newspapers prove nothing in opposition to what I here state. The writers in those papers have systematically exaggerated the qualities of the French ships for years past, representing that they could steam at impossible speeds, and carry as much fuel as any two of our ships. But these are statements which can be disposed of by scientific calculations of the most elementary kind; and the untruth of the French accounts has been so demonstrated over and over again. With the drawings and other particulars of 'La Gloire' before us we could tell with the greatest precision what fuel she can stow, how fast she can steam, and at what height her ports are above the water. We have not, it is true, all the details of the ship before us yet; but we have enough to demonstrate her real qualities with sufficient accuracy for my present purpose; and I confidently assert that she is seriously defective as a war-ship in many respects.

Now, from the very first our Admiralty has been averse to the construction of such vessels as 'La Gloire,' and to the rough and ready solution of the iron-cased-ship problem which she embodies. Whether their aversion was wise or not, under the peculiar circumstances of the case, I shall not presume to say; but that they could speedily have produced a fleet of ships in every way equal to 'La Gloire,' had they pleased, there is not the slightest doubt. Instead of doing this, however, they have asked, "How do we know whether a plated wooden ship, or a plated iron ship is the better? How do we know whether the plating should extend from stem to stern, or not? How do we know whether the side should be upright or inclined? or whether the plating should be backed with wood or not? or whether it should form part of the hull or not? or whether it should be made of rolled iron or of hammered? or what its thickness should be? or how it should be fastened?" and so forth. And while all these questions have been asked, we have pretty nearly stood still.

It is only fair to Sir John Pakington's Board of Admiralty to say, however, that, without waiting for answers to them, he ordered, as we have seen, the 'Warrior,' which is now afloat on the Thames. Those of you who, like myself, proceeded to Greenhithe in this vessel on the 8th of August, or who have visited her there since, will doubtless concur in the praise almost universally accorded to her. In all the yacht squadrons of the country there is not a handsomer vessel than the 'Warrior;' yet there are few iron-cased ships in the French Navy that will bear comparison with her as a vessel of war. She has been so often described in the public journals, and particularly in the 'Cornhill Magazine' for February last, that I need not stay to describe her here.

It is also to the credit of the present Board of Admiralty, that on their accession to office, they hastened to order the 'Warrior's' sister ship, the 'Black Prince,' which I doubt not is in every respect her equal. But why they soon afterwards built the 'Defence' and 'Resistance,' ships of 280 feet in length, 54 feet broad, and 3700 tons burthen, of only 600 horse-power, and plated over less than half their length, I cannot conceive. I am aware that these vessels are primarily designed for coast defence, and that their draught of water is more favourable than 'La Gloire's' for this purpose—theirs being 25 feet, and hers 27 feet 6 inches. But with engines of only 600 horse-power their speed must necessarily be low, and with so small a portion of their sides coated with thick plates they will be unfitted to stand that continued "pounding" to which a low-speed coast-defence vessel would be more exposed than a fast sea-going ship. The same objections hold to a certain extent against the 'Hector' and 'Valiant' class, which are of the same length and very nearly the same draught of water as the 'Defence' and 'Resistance;' but their increased engine-power of 800 horses (which has led to an increased breadth of 2 feet 3 inches, and an increased tonnage of 360 tons) will secure for them a higher speed, and their thick plating has been continued entirely round the main deck, so as to protect the gunners throughout the length of the ship; and these, therefore, though defective, are certainly better vessels than the others.

It is important to observe that, notwithstanding the long delay of the Admiralty, and despite all we have heard respecting experimental targets, the irresistible determination of Parliament to have a large iron-cased fleet has overtaken the Admiralty before they have obtained answers to any one even of the questions which we have before mentioned, and upon which they have been so long deliberating. The cause of this is undoubtedly to be found in the indisposition of the Admiralty to perform experiments upon a sufficiently large scale. Small targets, a few feet square, have been constructed and tested in abundance; but the results thus obtained correspond to nothing that would take place in practice against a full-size ship afloat. Not a single target of sufficient size, and of good manufacture, has yet been tested. The Admiralty are at length, however, having suitable structures prepared; and before long some of our principal doubts upon this subject will be resolved. Perhaps the slackness of the Board in undertaking these colossal experiments will be understood when I say that a committee of eminent private shipbuilders, including Mr. Scott Russell, Mr. Laird, Mr. Samuda, and Mr. R. Napier, have estimated that a target large enough to try half-a-dozen modes of construction would cost no less a sum than £45,000, and that another £45,000 would have to be expended upon an iron hull capable of floating this target, if the use of such a hull were considered indispensable.

But, however unprepared the Admiralty may still be, they have been compelled by the public sentiment, and by the power of Parliament, to make large additions to our iron-cased fleet during the last few months. When the House of Commons devotes immense sums of money to a national object with acclamations, and the single opponent of the measure acknowledges himself in error, the time for questioning and parleying upon points of detail is passed. And this is what has happened in this iron-cased ship business. The Government has declared a number of new ships necessary; Parliament has voted the requisite funds with unanimity and cheers; Mr. Lindsay has confessed himself in error; and the Board of Admiralty have been instructed to build the ships with all possible despatch. Let us now see what kind of ships they are to be.

The first of them, the 'Achilles,' which has recently been begun in Chatham Dockyard, so nearly resembles the 'Warrior' and 'Black Prince' that a very few words will suffice for her. The chief difference between her and those vessels lies, I believe, in the fact that her beam is slightly broader, and her floor somewhat flatter, than her predecessors, whereby her tonnage is increased from 6039 to 6089 tons, and her displacement from 8625 to 9030 tons. All her other dimensions, and all her essential features of construction, are exactly like those of the 'Warrior,'—from which it may be inferred that the method of plating the central part only of the ship, which was introduced by your distinguished Vice-President, Mr. Scott Russell, is still viewed with favour by the Admiralty designers. Mr. Scott Russell did not patent this invention, I believe; perhaps he will kindly tell us whether he has found his rejection of the Patent Law to pay him well in this instance.

In the class of ships which come next, however, the Admiralty have consented to forego the plan of plating amidships only, and purpose plating the ship from end to end with thick iron. But in order to do this it has been necessary to resort to larger dimensions than the 'Warrior's;' and hence these six new ships, three of which have just been contracted for, are to be 20 feet longer than her, 15 inches broader, of 582 tons additional burden, and 1245 tons additional displacement. As the displacement is the true measure of the ship's actual size below the water, or of her weight, it is evident that the new ships are to be considerably more than 1000 tons larger than the 'Warrior' class. As their engines are to be only of the same power, their speed will probably be less*. This diminished speed is one of the penalties which have to be paid for protecting the extremities of the ship with thick plates. Another will probably be a great tendency to plunge and chop in a sea-way. The construction of such vessels is a series of compromises; and no one can fairly blame the Admiralty for building vessels on various plans, so that their relative merits may be practically tested.

The cost of this new class of ships will exceed that of the 'Warrior' class by many thousands of pounds, owing to the increased size. But it will certainly be a noble specimen of a war-ship. A vessel built throughout of iron, 400 feet long and nearly 60 broad, invulnerable from end to end to all shell and to nearly all shot, armed with an abundance of the most powerful ordnance, with ports 9 feet 6 inches above the water, and steaming at a speed of, say, 13 knots per hour, will indeed be a formidable engine of war. And, if the present intentions of the Admiralty are carried out, we shall add six such vessels to our Navy during the next year or two. We must be prepared, however, to dispense with all beautifying devices in these ships. Their stems are to be upright, or very nearly so, and without the forward-reaching "knee of the head" which adds so much to the beauty of our present vessels. Their sterns will also be upright, and left as devoid of adornment as the bows. It should also be stated, as a characteristic feature of

* Since this paper was read at Manchester, I have learnt that the Controller of the Navy always intended these vessels to have a speed of 14 knots, and will give them sufficiently powerful engines to secure that, if possible.—E. J. R.

these six new ships, that their thick plating will not extend quite to the head at the upper part, but will stop at its junction with a transverse plated bulk bow some little distance from the stem; and this bulkhead will rise to a sufficient height to protect the spar deck from being raked by shot.

It has not yet been decided whether these new iron ships are to have their plating backed up with teak timber, as in the previous ships; or whether plating $6\frac{1}{2}$ inches in thickness, without a wood backing, is to be applied to them. The determination of this point is to be dependent, I believe, upon the results of the forthcoming experiments with the large targets to which I have previously adverted, and partly upon the recommendations of the Iron Plate Committee to which our President belongs, and which is presided over by the distinguished officer now present, Captain Sir John Dalrymple Hay, R.N. All that has been decided is, that whether the armour be of iron alone or of iron and wood combined, its weight is to be equivalent to that of iron $6\frac{1}{2}$ inches thick. The designs of the ship have been prepared subject to this arrangement, and provision has been made in the contracts for the adoption of whichever form of armour may be deemed best when the time comes for applying it.

All the iron-cased ships which I have thus far described are built, or to be built, of iron throughout, except in so far as the timber backing of the plates, the planking of the decks, and certain internal fittings may be concerned. I now come to notice a very different class of vessel, in which the hull is to be formed mainly of timber, the armour plating being brought upon the ordinary outside planking. The 'Royal Alfred,' 'Royal Oak,' 'Caledonia,' 'Ocean' and 'Triumph' are to be of this class. Their dimensions are to be—length 273 feet, breadth 58 feet 5 inches, depth in hold 19 feet 10 inches, mean draught of water 25 feet 9 inches, and height of port 7 feet. They are to be of 4045 tons burthen, and to have a displacement of 6839 tons. They are to be fitted with engines of 1000 horse-power. They are being framed with timbers originally designed for wooden line-of-battle ships, but are to be 18 feet longer than those ships were to be. They will form a class of vessels intermediate between the 'Hector' and the 'Warrior' classes, but, unlike both of them, will be plated with armour from end to end. They will be without knees of the head, and with upright sterns, and will therefore look very nearly as ugly as 'La Gloire,' although in other respects much superior vessels, being 21 feet 6 inches longer, 3 feet 5 inches broader, and of less draught of water. They will also be quite equal to her in speed.

It will occur to some now present, that in adopting this class of ship we have, after three years' delay, approximated somewhat to the 'Gloire' model at last. And undoubtedly we have done so in the present emergency, in order to compete with the movements which France is now making. At the same time we have not gone to work quite so clumsily as our neighbours. Instead of retaining the old line-of-battle ship proportions, we have gone somewhat beyond them; and have lifted all the decks, in order to raise our guns higher above the water. We have consequently secured a height of port or battery nearly 18 inches greater than 'La Gloire's'—an advantage which will prove valuable under all ordinary circumstances, and incalculably beneficial in rough weather.

The whole of the new iron-cased ships, including the five plated timber ships and the six 400-feet iron ships, will, there is every reason to believe, match 'La Gloire' in speed, supposing the engines put in them to be of the respective powers already mentioned—a condition which it is necessary to state, since there is, I regret to say, a probability of smaller engines being placed in some of them. But not one of all these new ships, the 'Achilles' only excepted, will have a speed equal to the 'Warrior's.' Perhaps we ought not to complain if our fleets are as fast as the French; but I, for one, certainly do regret that there should be any falling off in this prime quality of our iron-cased vessels. Iron and coal will give us fast vessels; and we have these in abundance. The truly admirable engines which Messrs. Penn have placed in the 'Warrior' show that we can command any amount of engine-power that we require, without incurring risk of any kind; and it would indeed be a blind policy to deprive ourselves of that speed which is pronounced invaluable by every naval officer and man of science who writes or speaks upon this subject.

I have thus far said nothing concerning the armaments of the new classes of vessels which I have been describing, because nothing has yet been finally decided respecting them. Nor would it be wise to decide this matter in the present state of our artillery, until to do so becomes absolutely necessary. We are, it is said, producing 100-pounder, and even larger, Armstrong guns with great success now, and may therefore hope for supplies of ordnance of at least that class for these vessels; but the modifications and improvements which even Sir William Armstrong himself has introduced, since he became our engineer-in-chief for rifled ordnance, have been so great that we have lost all confidence in the continuance of existing systems, and hold ourselves prepared daily for further changes. Before these new ships are fit to receive their armaments, or even before they have so far progressed as to make it necessary to fix the positions and dimensions of their ports, we may be put in possession of a far more effective naval gun than we can yet manufacture; and the best gun, wherever it may come from, must unquestionably be adopted for them. Whoever may produce it, we shall have, let us hope, the great benefit of Sir William Armstrong's splendid mechanical genius, and large experience, in manufacturing it in quantity at Woolwich. This is an advantage which should not be thought lightly of; for, whatever other views some may entertain, either through jealousy, or rivalry, or conscientious conviction, we must all agree in believing it a great piece of good fortune to have one of our very ablest mechanicians placed at the head of this great mechanical department.

I am able, however, to afford some information respecting the number of guns which the various classes of our new ships will be able to carry, and probably will carry. Of the 'Defence,' 'Resistance,' 'Hector,' and 'Valiant' I shall say nothing, because they cannot be considered fit for the line-of-battle, or suitable for any other service than coast-defence. Nor need I say more of the 'Achilles' than that she will in all probability be armed with such ordnance as may be found to answer best in the 'Warrior' and 'Black Prince.' We come, then, to the plated timber ships; and these I may usefully compare with the model French vessel. We know that 'La Gloire,' which is 252 feet 6 inches long, has an armament of 34 guns upon her main deck, and two heavy shell-guns besides—36 guns in all. Now our ships are to be more than 20 feet longer than her, and will therefore take two additional guns on either side; so that they will carry not less than 40 guns, if the ports are placed as close together as in 'La Gloire.' I need claim no greater advantage for them in respect of their armaments; but they are manifestly entitled to this. As a matter of fact, however, they will probably have a much more powerful armament. It is proposed, I believe, to arm them with about as many guns as 'La Gloire' on the main deck, all 100-pounder Armstrongs, and 16 or 18 other guns, principally Armstrongs, on the upper deck, making about 50 guns in all. If this intention be carried out, they will manifestly be much more powerful vessels than the original French ship. The newest and largest vessels, those of 400 feet in length, will each carry at least 40 Armstrong 100-pounders on the main deck, which will be cased with armour, as I before stated, from end to end. In addition to these they will doubtless have powerful ordnance on their upper decks, for use under favourable circumstances. But all these arrangements are, I repeat, liable to change*.

Unfortunately, I am unable to compare the power of these vessels with that of the largest of the French iron-cased ships, owing to the absence of all detailed information concerning them. I trust, however, that the Admiralty are in possession of the necessary particulars, so that the delay which has taken place may be turned to the best possible account by securing superiority for our fleet. If this be so, then we shall, after all, profit by the apparent sluggishness of our naval authorities. In fact, if England had France only to consider, and if the Government of England were embodied in a single sagacious ruler as absolutely as is that of France, so that we could ensure prompt action in an emergency, the very best course for us to pursue in this great naval competition would be to leave the lead in the hands of the French Emperor, taking care to add a ship to our Navy for every one added to his, and to make ours much more powerful than his. In the event of a war, our manufacturing resources would be abundantly sufficient to secure for us a further and almost instant preponderance. The game which we should thus play would be

* Since this paper was read, the issue of 100-pounder Armstrongs has been suspended. —E. J. R.

both politic and economical. But with other naval nations to compete with, and with the inertia which inevitably, and often happily, attends a constitutional and parliamentary system of government, we cannot afford to play games of skill with omnipotent emperors, but are bound to be ever ready to assert our preeminence.

I have a little information concerning the 'Solferino' and her sister French ships which it may be useful to give you. Her length is 282 feet, breadth 54 feet, mean draught of water 26 feet, displacement 6820 tons, thickness of armour plating $4\frac{3}{4}$ inches, nominal horse-power of engines 1000. Her plating extends from stem to stern over the lower gun-deck, and rises up amidships sufficiently high to cover two decks. She is furnished with an angular projection or prow below the water, for forcing in the side of an enemy when employed as a ram. I regret my inability to add materially to these details of the largest French ships.

Let me now consider briefly the pecuniary phase of this iron-cased ship question. We may fairly assume that the average cost of such vessels will not be less than £50 per ton, and that their engines will cost at least £60 per horse-power. Supposing these figures to be correct, then the hulls of the eighteen ships which we have been considering will cost us £4,681,600, and their engines £1,143,000—together nearly *six millions* pounds sterling. When masted, rigged, armed, and fully equipped for sea, they will of course represent a much larger sum—probably nearly *eight millions.* These estimates will afford some faint conception of the nature of that "reconstruction" of the Navy upon which we may now be said to have fairly entered, in so far as the ships themselves are considered.

But I must not conceal the fact that the introduction of these enormous iron-cased ships has entailed upon us the construction of other colossal and most costly works. We have now to provide immense docks for their reception; for we at present possess none suitable to receive them. Nor must these docks be of large proportions only; for in order to sustain ships burdened with thousands of tons of armour, they must be furnished with more substantial foundations and walls than any hitherto constructed, and be built of the best materials and with the soundest and firmest workmanship.

Many considerations combine to exalt the importance of this part of my subject. In the first place, the tendency which iron ships have to get foul below water will render it necessary to dock our new ships frequently, under ordinary circumstances, and whether we go to war or not. In the second place, for aught we yet know, these ships may be found to give signs of local weakness as soon as they are taken on an ocean cruise, and to require such repairs and strengthenings as can only be performed in dock. Again, being steamships, they will be continually liable to accidents in connection with the engines or the propelling apparatus; and with many such accidents docking will become indispensable. And so I might proceed to multiply examples of this kind. But there is one consideration which is paramount, and which may therefore be stated at once: we dare not send these ships against a French fleet unless we have docks for them to run to in the event of a disaster. We know not what may happen to these altogether novel structures until they have been exposed to successive broadsides from a heavy naval battery; and it would be madness to send them out to encounter a powerful fleet of vessels as strong as themselves unless we are prepared to open docks to receive them in case of necessity.

I have said that we are at present without dock accommodation for these ships; and it may be desirable to illustrate the correctness of this statement in detail. What we require for them in each case is, first, deep water up to the entrance of the dock; secondly, a depth of not less than 27 or 28 feet of water over the sill of the dock; and thirdly, a length on the floor of the dock of 400 feet. Now, these three conditions are not combined, I believe, in any dock in Great Britain—certainly not in any of Her Majesty's Dockyards. At Portsmouth we have just completed a pair of docks which can be thrown into one, 612 feet long. But over the bar of Portsmouth harbour there is a depth of 17 feet only at low water, 27 feet at high water *neaps,* and 30 at high water *springs.* Consequently, these large iron-cased ships, if they went to Portsmouth in a dangerous state, or in hot haste to get to sea again, would nevertheless have to wait for the very top of the tide before they could get either in or out. But even if there were no bar, the Portsmouth dock would still be unavailable in such an emergency; for the depth of water over the sill of one portion of it is but 25 feet at high-water springs. It is into this dock that the 'Warrior' is shortly to be taken for the purpose of having her launching cleats removed, and her bottom cleaned. As she can at present afford to wait upon the tide without inconvenience, there will be no difficulty in this case. But in war time it would never do to keep such an important member of your squadron fretting for the tide at Spithead, or to have to lighten her before she could cross the dock's sill. At Devonport, again, the longest dock is only 299 feet long over all; but I am happy to state that one is in progress of construction 437 feet long, 73 broad, and 32 deep at the sill. At Keyham, the longest dock (the South), which is 356 feet in length, has but 23 feet depth at the sill, while the North, which has 27 feet, is but 308 feet long. At Pembroke, there is a dock of 404 feet, but it has a sill of 24 feet 6 inches only. The longest dock at Sheerness is 280 feet; at Woolwich, 290; and at Chatham, 387, but the last has but 23 feet 6 inches at the sill. At Deptford there are but two docks, opening into one, and they are very shallow. There are a few large private docks in the country which come very near to our requirements. There is the Canada Dock at Liverpool, for example, 501 feet long, 100 broad, and with 25 feet 9 inches over the sill. There are also No. 1 Dock at Southampton, and the Millbay Dock near Plymouth, of which the former is 400 feet long with 25 feet over the sill, and the latter 367 with 27 feet 6 inches over sill. But none of these answer all our requirements, nor could we avail ourselves of more than one or two of them in time of war if they did.

If we turn to the French coast, we shall find that in this matter also we are far behind our neighbours. At Cherbourg there are two docks 490 feet long and 80 broad; two 380 feet by 70; two 350 feet by 65; and two smaller ones besides. At Brest, again, there is building a double dock 720 feet by 90; and there are also two 492 feet by 60, and two smaller. At L'Orient there is one 350 feet long, and another (building) 500 feet. At Toulon there are two in progress, one 406 feet long, and the other 588, beside several smaller docks which have existed for some time. I cannot give the depth of the sills of any of these French docks; for I have been unable to obtain that element in any single case even, and I am assured that no account of it is anywhere recorded in this country. But there is no good reason to doubt that a proper depth has been given in most instances.

You will now be able to comprehend the advantage which France has secured in this matter of dock accommodation for her iron-cased fleets, and will readily discern the danger to which we should be exposed in the event of an early war with that country. A single action might so seriously cripple both fleets as to render large repairs necessary; but France alone would be capable of renewing her strength. It would be our lot to lie crippled in our harbours, while she captured our commercial vessels and menaced our coasts.

I am perfectly well aware that a large increase of dock accommodation is to be supplied at Chatham forthwith. But our Channel and Mediterranean fleets must not depend upon docks at Chatham, which cannot be reached from the south until a long passage has been made, the Nore sands threaded, and an intricate and shallow river navigated. We must give to our ships the advantage which Cherbourg secures for the French, and which they propose to augment by establishing at Lezardrieux* an immense steam arsenal, protected by an impregnable series of defences.

It will now be seen that, in order to place ourselves upon an equality with the French navy, no less than to meet the certain emergencies which must arise with our reconstructed fleets, we ought without delay to found a colossal dock establishment on some favourable point of our southern shores, furnished with the means of carrying on extensive repairs in time of war. The most suitable of all positions is probably that of the Southampton Water, the shore of which, at the entrance to the river Hamble, presents conditions and circumstances which finely qualify it for the purpose. If we are wise enough to build a set of suitable docks there before the time of war arrives, we shall have the satisfaction of knowing that the largest iron-cased ships now in contemplation will be able to run in and be docked with all their stores on board, and everything standing. And nothing less than this should satisfy us.

* See an admirable article in Capt. Becher's 'Nautical Magazine' for July, 1861.—E.J.R.

The Income-Tax. *By the* Rev. Canon Richson.

The author quoted the report of the late Committee of the House of Commons, in which they declined to interfere with the present mode of levying the tax, and described the case of a clergyman deriving £150 from a living in a large parish in Manchester, the extent of which necessitated the employment of two curates. The clergyman gave up the whole of his income towards the payment of his assistants, but both he and they were compelled to pay income-tax, though he did not receive a farthing in the way of personal emolument. Taking therefore into consideration the refusal of the report to recommend any modification of the present Acts for levying and collecting the income-tax; that the number of persons who suffer unjustly from the operation of the present Acts is very large; that there are sufficiently definite objections to their operation in which persons concur, without involving those subjects of discussion wherein there is little immediate prospect of agreement; that the operation of the present Act leads to habitual frauds, injurious to commercial integrity; and, finally, that the efforts of individuals are unequal to the necessary conflict with the prejudices and interests arrayed against such a revision of the Acts as their very terms appear to justify,—he considered that, after so unsatisfactory a result of two committees of the House of Commons as was indicated by the present report, it was useless to expect equitable improvement, unless they who are dissatisfied with the existing anomalies are prepared, for the present, to sink their differences of opinion in respect to an entire modification of the bases of the tax, and to form an extensive association, with the restricted and clearly defined object of promoting the application of the Income-Tax Acts in harmony with their declared objects.

Can Patents be defended on Economical Grounds? *By* Professor J. E. T. Rogers, *M.A.*

The author contended that patent laws did not stimulate invention; they did not come within the definition of protection to property and the acknowledged duty of the state to maintain intact the labour of individuals; they acted as a hindrance to improvement by being a check on the freedom of beneficial discovery; they were an illogical acknowledgment that the accidental property of discovery was the ground for allowing a sole property. All reasonable advantages were secured by secresy, and were constantly superseded by secresy; and they were a tax in the fullest sense on the consumer.

On the Definition and Incidence of Taxation. *By* Professor J. E. T. Rogers, *M.A.*

The author gave the following definition of a tax:—"A tax is a contribution imposed by an acknowledged authority on a community, for the purpose of public utility, whether this utility be the discharge of obligations incurred for past services or for the maintenance of present capacities of production, the tax being levied on the ground that the utility procured, service rendered, or functions performed by the administration of this contribution, cannot possibly be procured, rendered, or performed by individuals, or by inferior cooperative agencies, and cannot be so economically discharged by them." The incidence of a tax he indicated to be as follows:—"If a tax be levied on sources of income which are of an elastic character—that is, on the services of productive labour,—it must be paid by the consumer; and though such an incidence may be inexpedient to the community, it is not unjust to the person who is the channel of the tax. But if it be levied on income which is not elastic, it may be unjust to the person who pays it, as well as inexpedient to the person or persons who represent the consumer."

On some Account of the Manchester Gasworks. *By* John Shuttleworth.

Manchester was the first place in which the regular and complete application of gas for economical purposes was successfully tested. This was effected under the direction of Mr. William Murdoch, in 1805, at the cotton-mill of Messrs. Phillips and Lee, and had made Manchester a sort of starting-point in all historical notices of the subject. Their townsman, Dr. Henry, was the first to direct attention to the purification of gas; and, further, the Act 5 George 4, c. 133, which passed in 1824, under which the Commissioners of Police for Manchester were authorized to establish gasworks for lighting the town, was, he believed, the first Act ever granted by Parliament that empowered a municipal body to apply public funds to the carrying on of a manufacturing business for the benefit of the public. Until that Act was obtained, it was an established principle in the legislation of this country not to permit public bodies to become traders. It appeared, then, that in connexion with gas Manchester enjoyed the distinction of being the locality where its practical use on a large scale was first shown, of ranking among its citizens the eminent chemist by whose researches its purification was effected, and of removing the Parliamentary restrictions that prevented municipal bodies from deriving profits for public use from its manufacture. The Commissioners of Police, who managed the affairs of the town under an old Police Act, the 32nd George III., which passed in 1792, began the public use of gas by fixing a single lamp over the door of the then police office in Police-street, at the bottom of King-street. He well remembered the crowds that night after night gathered in front to gaze at it. As the use of gas spread, its superiority to all other light made the public anxious to obtain it for private consumption; and several public meetings were held for the purpose of urging the Commissioners of Police to extend the works so as to supply the general demand. The Commissioners made an appeal to the leypayers at large; and at a meeting held on the 30th of April, 1817, it was resolved:—"That it will be expedient to adopt the proposed mode of lighting the central parts of the town with gas, and, for the purpose of effecting this object, to raise the police rate from 15*d.* to 18*d.* in the pound." The gasworks were enlarged, a "Gas Committee" was established; but as the right of the commissioners to sell gas to private consumers was uncertain, it was thought desirable to obtain a special Act of Parliament to legalize what had been done and to give power to continue the works, prescribing the application of the funds derived from them. While the commissioners were preparing their measure, a notice appeared on the 20th September, 1823, from persons entirely unknown in Manchester, and without any previous intimation of their intention, to apply to Parliament for a bill to authorize the establishment of a "Manchester Imperial Joint-stock Oil Gas Company, to light with oil or other gas the town and parish of Manchester." On this notice appearing, measures were taken to oppose the project, and at the same time to promote the previously intended purpose of obtaining a Gas Act for the town. In furtherance of these objects meetings were held in Manchester, Salford, Ardwick, and other townships of the parish. Though the opposition to the Oil Gas Bill was thus formidable, the promoters continued their efforts, and might have succeeded; but in getting up petitions in favour of the bill they had resorted to the grossest fraud in attaching forged and fictitious signatures, and, on these frauds being proved to the committee by the clearest evidence, the committee to which both bills had been referred at once indignantly rejected the Oil Gas Bill and adjourned without making any report, alleging that they dispensed with this customary formality from a motive of mercy to the parties, inasmuch as they could not make a report without bringing the authors of the fraud and contempt to justice. So strong and general was the indignation excited in the House, that on an attempt being made a few days after to revive the committee, the motion was negatived, not in the usual way by a quiet orderly vote, but, as it is stated in the newspaper reports of the time, "by a thunder of Noes." The resentment thus provoked by one party had, perhaps, a reactionary influence in favour of the other; for the defeat of the Oil Gas Bill was speedily followed by the passing of the Manchester Act, thereby practically recognizing the principle that such establishments might be created by public funds and conducted by public bodies for the public benefit, and, further, that the object to which gasworks especially are subservient are more likely to be secured by a general establishment conducted under effective public control by a public body than by any private association founded solely for private gain—in short, that such establishments are not only legitimate in principle, but are even the best (because the most certain and convenient) means of effecting those most important public improvements which progress and circumstances make necessary in towns, which might not be otherwise effected. The Act unfortunately left the constitution of the body which, under the Act of 1792, governed the town, and from which the gas directors had to be chosen, unaltered. The governing body was not composed of a limited number of persons chosen as representatives, but was constituted of all the inhabitants who paid a rent of £20 a year. Under such a system it was clear that whenever there was a strong collision of opinion on public questions, persons on both sides would qualify in such numbers as utterly to destroy the deliberative character of the public meetings that might be held. In the proceedings, both with respect to gas and other public affairs, that took place for years after the passing of this Act, so great was the excitement that prevailed, that crowds of qualified inhabitants became Commissioners of Police; and for a long period the meetings that were held were characterized by the most disgraceful turbulence and disorder. At one meeting alone, in 1827, no less than 665 persons qualified as commissioners. At these meetings the most extravagant propositions were brought forward, such as, for instance, that gas should be supplied to consumers at cost price. The parties most prominent and offensive in this violent agitation were chiefly the lowest class of shopkeepers and publicans. Then followed an agitation for the sale of the gasworks; but this was eventually suspended by the appointment of the late Mr. Thomas Wroe to the comptrollership of the works. This was quite an epoch in the history of the works. In the first year, Mr. Wroe reduced the price 5 per cent., and raised the production from 88 millions of cubic feet to 96 millions, or 9 per cent., and increased the profits from £10,200 to £13,500, or 34 per cent. In the ten years that Mr. Wroe was connected with the works he reduced the price from 10*s.* 6*d.* to 5*s.* 9*d.*, and raised the annual profit from £10,200 to £31,700. The benefit derived by the town from Mr. Wroe's services amounted to an annual sum of £45,416. This was stated in a report of the Finance Committee, bearing date August 22, 1842, which he thought ought to be published for general circulation, as it contained particulars of the services of one who had not yet had justice done to his unparalleled work as a public servant.

For the introduction of the Municipal Corporations Act to Manchester they were indebted to Mr. Alderman Neild, who originated the movement, and was untiring in his exertions until it was accomplished. The Municipal Act, among its many other advantages, gave a security and permanence to the gas establishment which it could not be considered to possess previously. The consequences had been highly important. To the inhabitants it had supplied the best and cheapest light that exists. To the public at large it had contributed regularly funds for widening old and forming new streets to an extent that had afforded needful accommodation for the vast increase of traffic, of population, and merchandize that had grown up among them, and which, without such aid, would probably have been actually prevented by the want of space in the streets and thoroughfares, which was essential to its existence. In both social and political economy, facility of communication and transit was one of the most important elements of national prosperity, and demanded unceasing attention to every available means for securing it. In this respect the Manchester gasworks had been especially useful. Before their establishment it was the standing and universal reproach of Manchester that it was the worst and most inconveniently built town in Europe. It possessed no fund for general improvements, and was so rapidly increasing as to make from day to day the necessity of such a fund more alarmingly apparent. Without the funds derived from the gasworks, the physical necessity of wider and shorter streets would either have put a stop to the growth of the traffic, or have rendered absolutely imperative a resort to large improvement rates, thus not only most injuriously affecting the value of property throughout the town, but also checking and depressing all other interests. Such were the exigencies of the town in this respect, that at a meeting of the Commissioners of Police in 1827, a scheme of necessary improvements to meet the rapidly advancing wants of the community was brought forward, which involved an estimated cost of from one to one and a half million sterling. He thought it was a happy circumstance for Manchester in a threatened necessity of such vital importance to its prosperity, that a fund existed in the profits of the gasworks of sufficient magnitude to equal the demand. That these estimates were not overrated was clear from the fact that, in addition to improvements still in progress and still wanted, the payments from the gas profits for the purposes then contemplated have amounted to more than £700,000, besides debts incurred that were yet owing. In the first year of the establishment of the gasworks the profits amounted to £263 10*s.* 5*d.* In the following seven years they amounted to £20,000, and of this £15,000 to £17,000 was paid towards the erection of the Town Hall. From 1825 to 1839 inclusive (from the date of the first Gas Act to the grant of the charter, a period of 15 years) the profit was nearly £172,000, or an average of £11,500 a year; and from 1840, when he became a member of the Gas Committee, to 1859, when that connexion ceased, a term of 19 years, they amounted to £660,000, or an average of nearly £35,000 a year, or treble that of the preceding 15 years. The price to the consumer during the same period had been reduced from about 16*s.* to 4*s.* 6*d.* (in 1859) per 1000 feet; and but for a resolution of the Town Council in 1851, by which one-half of the profits was diverted from improvements to relieve the water rate, would certainly have been reduced ten years ago to a medium of 4*s.* per 1000 feet. According to the last published report of the Gas Committee, to June 24, 1860, the amount of capital in the gasworks was £501,326; gas produced in the year ending June 1860, 779,150,000 cubic feet; rental, £154,658, which was equal to an average charge of about 3*s.* 10¾*d.* per 1000 feet. The price of gas within the city is from 3*s.* 8*d.* to 4*s.*, or a medium of 3*s.* 10*d.* The cost of cannel, £56,177, equal to 1*s.* 3¼*d.* per 1000 feet; cannel consumed, 76,039 tons, which showed a production of 10,240 per ton. By the Gas Committee continuing to attend to the quality of the gas so as to secure the highest purity and illuminating power, and by the council so regulating the price by fixing it at as low as was commensurate with the capital employed and the business done, they might expect not only a continuance, but an augmentation of the benefits of which it had been a certain and important source.

On the Altered Condition of the Embroidery Manufacture of Scotland and Ireland since 1857. *By* JOHN STRANG, *LL.D.*

The author enlarged upon the advantages of this particular occupation in encouraging artistic skill and taste, and in affording occupation for females at their own homes. He deplored the capricious fickleness of female fashion, which had led to a great decline, and said it was to be hoped that so long as the tasteful designer continued to dream after some new shape or pattern, so long as the unwearied energy of the manufacturer was exerted to create new articles of utility, and the restless activity of the merchant was spent on discovering some new market for their disposal, the future of the muslin embroidery manufacture would ere long become, as heretofore, a pleasing and profitable occupation during the intervals of field labour and domestic duties to at least as great a number as it formerly did of the industrious females of Scotland and Ireland.

On the Comparative Progress of the English and Scottish Population as shown by the Census of 1861. *By* JOHN STRANG, *LL.D.*

If some distant and untutored foreigner happened to cast his eye over the map of the world, and were told by some enlightened bystander that within the comparatively small islands of Great Britain and Ireland there resided the elements of a first-rate political power, he would no doubt feel some little surprise at the intelligence, particularly were he, at the same time, informed that within the boundaries of Great Britain itself there was only a surface area of about 57 millions of statute acres. But the foreigner's surprise would be perhaps still greater were he further told that, while the southern portion of the island, called England and Wales, with a surface of little more than 37 millions of acres, had a population (as ascertained by the late census, exclusive of the army and navy, and merchant service abroad) of 20,061,725, the northern portion, called Scotland, with a territorial surface of upwards of 20 millions of acres, contained only 3,061,329 inhabitants. Such, however, are the real facts of the case; and those, like ourselves, who are acquainted with the distinctive physical peculiarities of the two portions of Great Britain will feel little wonder about it. There is, however, a subject connected with this territorial division of England and Scotland, and their distinctive populations, which is not so easily understood; we mean the fact, as shown by the census returns of the present century, that there has existed for some considerable time, and particularly of late years, a marked difference in the ratio of the progress of the population within the limits assigned to the northern and southern portions of Great

Britain respectively. By a table before me, it appears that the population of England and Wales has, in the course of sixty years, increased to the extent of 10,905,554, whereas that of Scotland has advanced to the extent of only 1,452,909, exhibiting an increase on the part of England and Wales of 119·1 per cent., and on that of Scotland of only 90·3 per cent.; and if we merely compare the progress of the population of the two divisions of the island respectively during the last ten years, we find that, while England and Wales show an increase of 12 per cent., Scotland only exhibits an advance of 5·9 (or about 6) per cent. The question then naturally arises, how can this great and important discrepancy between the rates of progress in England and Scotland, particularly as existing between the years 1851 and 1861, be explained? Has it been occasioned by a different birth and death rate ruling in the respective portions of the island? or is it to be found in a larger proportional rate of emigration on the part of the North to that of the South? And if the latter be the case, what may be the probable causes which have led to that higher emigration spirit?

Let us then attempt to discover what has been the actual natural increase of the population in Scotland, as deduced from the excess of births over deaths, since 1851. And here a difficulty meets us on the threshold—the fact that before the 1st of January, 1855, there was no public register of births, deaths, and marriages kept in Scotland; and it is therefore only from the latter period that we can obtain any authentic figures wherewith to deal. During the last six years and a half, the actual increase of the population from the excess of births over deaths amounted to 260,392; and, assuming that the average annual birth and death rates then existing differed but little from those existing during the three and a half years that preceded the passing of the Registration Act for Scotland—which rates were, say, birth-rate 3·41 per cent., death-rate 2·08 per cent.—then it would follow that during that period of three and a half years preceding 1st January, 1855, the births must have amounted to 346,115, and the deaths to 211,120, showing an excess of births over deaths of 134,995, which, when added to the excess of births over deaths during the last six and a half years, makes a total natural increase of the population in ten years, within the boundaries of Scotland, of 395,387, or at the rate of about 13·6 per cent. It is therefore quite evident that, had Scotland not been subject to the effects of a serious emigration, her population of last census would have amounted to 3,284,129, instead of 3,061,251. If such, therefore, may be taken as a proximate picture of the real natural progress of the population of Scotland, it necessarily follows, considering the immigration from Ireland into the west of Scotland, that the tide of emigrating Scotch to other countries must have been very great, especially during the last ten years, seeing that, in addition to all the Irish immigration (which, however, has not been so large for these four or five years past), there must have gone out from Scotland no fewer than 222,878 persons, being the difference between the natural increase from the excess of births over deaths and the increase as shown by the late census. According to the returns made to the Registrar General by the Government Emigration Board, we find that during the last two years the estimated number of Scotch who have emigrated with the knowledge of the same board has amounted to 183,627, leaving 39,251 which must have left otherwise, either to recruit the army and navy abroad, to push their fortunes in various parts of the globe, unaccounted for by the Emigration Commissioners, or, what is more likely, have gone to swell the population of England.

That the population of England has been greatly increased from immigration will at once appear evident when it is stated that in the ten past years the English-born emigrants have amounted to 640,210, the natural increase of her population only exhibits 136,460 more than her ascertained population by the census, showing an unaccounted-for deficiency of 503,740, for which she must have been mainly indebted to Scotland and Ireland. That an emigrating spirit has manifested itself on the part of the Scotch more than the English is certain from the fact that, taking the mean population for the last ten years of each country, we shall find that, had Scotland only emigrated proportionally to England, the Scotch emigrants ought only to have amounted to about 100,000, whereas the numbers stated by the Commissioners are 183,627. If the emigration from Scotland has thus been so disproportionally great, it may be asked from what particular quarter of the country has this spirit chiefly manifested itself? or, in other words, in what division of the country has the population absolutely shown a decline? It appears, from a table, that in twelve out of the thirty-three counties of Scotland there has been, since the census of 1851, irrespective altogether of the natural progress of the population by excess of births over deaths, a diminution of the inhabitants to the extent of 31,825; and as those counties are almost entirely agricultural and pastoral, the fact would seem to indicate that either manual labour was less wanted in these particular districts, or that a better remuneration for labour and industry was offered elsewhere. For a striking contrast to this state of things in the agricultural and pastoral parts of Scotland, we have only to look to the census figures of the commercial, mining, and manufacturing county of Lanark, where we find, in the course of the last ten years, an increase to the population of no less than 101,390! The fact is, the increase of the population is almost entirely limited in Scotland to towns, and to these of the largest kind—the increase in towns being 10·9 per cent., whereas the rural districts only show an advance of 0·9, or not 1 per cent.; or, if Scotland be divided into three great divisions, viz. insular, mainland-rural, and towns, the insular will show a decrease of 3·6 per cent., the mainland-rural an increase of 3·9 per cent., and the towns an increase of 12·9. But, to show still more forcibly the decline that has taken place among those residing in the rural portions of Scotland, it may be mentioned that the small increase stated as occurring in the mainland-rural district of 3·9 per cent. is owing almost entirely to the increased population of the smaller towns situated within the limits of that great division of the country. The leading deduction, then, to be drawn from these dry statistical details is simply this, that there has existed for some time a manifest tendency on the part of the inhabitants of the country districts, and particularly of those dwelling amid the highlands and islands, to quit a land where rural labour was but little wanted, and pastoral care was poorly paid, for other countries, where both were in good demand and highly compensated, or for towns and cities, where the hardy and unskilled labourer is almost always sure to find employment. That this emigrating spirit in search of future prosperity has proved as yet as advantageous to Scotland as it has certainly been to Ireland, will scarcely be denied, seeing that it increases not only the value of the labour, and raises the condition of those who remain behind, but elevates the position and increases the comforts of those who go away. And although there must ever be felt a pang on the part of a pilgrim family when abandoning for ever the cherished scenes of childhood, even when those are associated with nothing better than the comfortless home of the Highland cottar, still the mutual personal benefit that results from this separation has been generally found to be, to those gone and to those left, well worthy of the temporary pang.

Among the immediate causes which have led to the late depopulation of the Highlands and islands, and the partial diminution of the inhabitants of the other rural districts of Scotland, we shall only allude, first, to the great enlargement which has lately taken place in the sheep-walks and agricultural farms, particularly in the northern parts of the country, thereby diminishing a host of small master graziers, and even smaller agricultural tenants, each and all of them without energy and without capital; secondly, to the discouragement given to the continuance of unnecessary cottars idly occupying the country; and thirdly, to the effects and results of the late Highland famines, which have, alas! too sadly taught the poor and perishing denizens of a country that cannot maintain them to flee for refuge to one more kind and hospitable. If, however, from the returns of the present census we have been told that the rural portions of Scotland have, with respect to population, remained either stationary or have shown a tendency to decline, it is, at the same time, certain that, in the great centre of trade, mining, and manufactures (we mean in Glasgow) there has been a most marvellous increase in the numbers of its inhabitants; for, while at the commencement of the present century that city and its suburbs only contained 83,769 persons, the last census revealed the fact that its population, with that of its new-world increasing suburbs, amounted to 446,395, which, when compared with the population residing on the same territory in 1851, showed an increase of no less than 86,257 during the last ten years, or a rate of 23·95 (or nearly 24) per cent. That this increase has mainly arisen from a constant immigration from all parts of Scotland, and also from Ireland, is no doubt certain; for if we assume that the last year's birth-and-death rates (which were, births 3·87 per cent., deaths 3 per cent.) have been the average rates for the last ten years, which we believe is not far from the truth, and that the mean population during the same period may be fairly assumed to have been 403,000, it will then follow that the natural increase, arising from the excess of births over deaths, could not have amounted to more than about 35,000, which, being deducted from the ascertained increase as shown by the late census, proves that the increase of the city and suburbs must have been supplemented by an immigration of upwards of 50,000.

That Glasgow, indeed, has been chiefly indebted during the last half century to the immigration which an increase of capital and an active and multifarious industry have induced, cannot better be illustrated than from the facts which our own lately printed analysis of the enumeration returns of the Glasgow census then exhibited. From these the fact may be gathered that, independent of the many thousand individuals that have been attracted to that centre of Scottish industry from all quarters of Scotland, there were found within the limits of its municipality alone, on the 9th of April last, no less than 10,809 native English, 63,574 native Irish, 827 foreigners, and 1440 colonists, being about 20 per cent. of the whole of that population. While Scotland, from its improved and still improving system of agriculture and cattle-rearing, may feel well content to part with her supernumerary and unemployed peasantry, either to add to the prosperity of her urban seats of industry, or to continue to fulfil the old adage, that, in every nook of the world where any good is to be got, there is to be found a Scot, a rat, and a Newcastle grindstone, she at the same time cannot but feel assured, so long as her soil is daily becoming more productive, and her manufactures, mining, and commerce are advancing, and her cities, harbours, and railroads are extending as they are at present found to be, that she is still on the pathway of prosperity, even although the census has truly proclaimed that the progress of her population has only exhibited an increase of scarcely six per cent. during the last ten years of her history.

Notes on the Progress and Prospects of the Trade of England with China since 1833. *By* Colonel SYKES, *M.P.*, *F.R.S.*

Our present and prospective relations with China, both commercial and political, are so highly important, and involve such serious consequences, that a few observations on those subjects may neither be inopportune nor uninteresting. Whether our past policy towards China has been justifiable or not, the extension of our commercial relationns with the Chinese is sufficiently remarkable. In the year 1814 the total amount of imports and exports on British account was about $5\frac{3}{4}$ millions sterling. In 1826 the value exceeded seven millions; and for the last five years of the East India Company's monopoly the average value of the Company's and the private trade in which they permitted their servants to engage approached to ten millions sterling. Since the Act of 1833, which deprived the East India Company of their monopoly, as might be expected, a rush of competing interests has increased the trade since 1834 fully fourfold. In 1856, according to statements which appeared in different numbers of the Hong Kong Government *Gazette*, the value, independently of the opium trade with India, amounted to £17,526,198. In 1857, the imports were £4,783,843; but the exports were £12,742,355. So far as the legal trade was concerned, the exports trebled the imports; but there was another article of commerce of which there was no official record kept. He referred to opium, which in 1857 amounted to four millions. Still the exports exceeded the imports by nearly four millions, which must have been paid to China in silver; but as the balance of trade between India and China had always been in favour of India, most of the silver from Europe found its way to India through China in payment for opium, and this fact assisted to account for the silver which poured into India annually, and did not leave the country again. From the years 1834–35 to 1858–59, India received £123,143,696, in bullion, of which only £19,752,653 left the country again. A remarkable progress had taken place in the export trade of Shanghai—a fact which presented some anomalous and conflicting considerations. Since the year 1853 the rebels or Taepings had been in possession of Nankin, the ancient capital of China, and of several great tea- and silk-producing provinces in the Yantsze Kiang; and Shanghai had to be supplied either from these provinces or from provinces beyond the rebel territories and still under the Tartar authorities, but whose products would mostly have to pass through the rebel territory to reach Shanghai. A portion of the Europeans in China had exhausted damnifying epithets in reference to the rebel character and proceedings. They were "bloodthirsty brigands," &c. He was not an apologist of the rebels; but he could not refrain from asking himself how it was that the trade of Shanghai could have flourished in the way it had done if the accusation that they were desolators and exterminators were literally true. Annually increasing quantities of tea and silk could not be produced from "howling wastes;" and those products, if for the most part coming from provinces under Tartar rule, must have passed unmolested through Taeping territories, though as brigands they ought to have plundered them. The Taepings professed to have a divine mission to extirpate the Tartars, their foreign rulers, and to destroy idolatry; and in prosecuting these objects great atrocities no doubt had been perpetrated; but, in respect to the rural population as contra-distinguished from the Tartars, the fact was patent, that when unexpectedly repulsed in their attack upon Shanghai, in August 1860, by French and English troops, although exasperated by a sense of betrayal, in their retreat they left uninjured the standing crops around Shanghai, and they did not molest Europeans. The nature of this paper will not admit of the discussion of the conflicting opinions promulgated respecting the character and conduct equally of the rebels and of the Tartars. There could be no doubt that they practised towards each other the most revolting atrocities, such as were the usual accompaniments of civil war exasperated by religious fanaticism. He could only consider the question in relation to the prospects of the British trade with China. The expenditure of British blood and British treasure in three successful wars had extorted from the Tartars all the facilities that the British trader desired to have, leaving, however, in Tartar breasts a burning resentment at the degradation of the Imperial government, and in Tartar officials a manifest disposition to obstructive subterfuges in carrying out the treaty of Tien-tsin. The Taepings or rebels on their part issued proclamations professing amity for foreigners, calling them "Christian brethren," and inviting them to enter into commercial relations, but with one exception. The traffic in opium they denounce as a religious ordinance, and threaten the penalty of death to those who engage in it. The tax-payers of England, therefore, would have to determine whether we were to tread in our former steps, and, for one article of commerce, waste life and money to force upon a reluctant people, for selfish gain, a deleterious product; while, at the same time, we crushed a national movement to throw off a foreign oppression, which under analogous circumstances in Europe had had our warmest sympathy, and at the success of which all freemen rejoiced.

On some Exceptional Articles of Commerce and Undesirable Sources of Revenue. By Charles Thompson.

The object of the paper was to show that the malting of barley and distillation of grain are the means of a great and serious waste of food, enhancing the scarcity which is so injurious to the welfare of the people; that the liquor traffic and the drinking usages it promotes are barriers between our wants and an abundant supply of food, and that, by passing "the admirable suggestion of the United Kingdom Alliance, endorsed by Lord Brougham, and hailed by popular acclamation everywhere," a Permissive Bill to enable a large majority in any district to suppress the common sale of intoxicating liquors, parliament would legislate on principles of social justice, sound political economy, and sagacious statesmanship. The writer, in conclusion, remarked as follows:—"That the food of a people is their life—the means of their existence; and that whatever tends to render human food scarce in quantity, or to deteriorate its nutritious quality, or converts it into an element of mischief and disease, must be anti-social, immoral, irrational, and highly criminal. Reason, morals, political economy, and social science, all concur in condemnation of any system that inevitably destroys that which is essential to the life, the health, and the happiness of the people. To destroy food is, in effect, to destroy that life and health and happiness that food sustains. Hence, it becomes one of the first duties of statesmanship to provide and to husband the means of subsistence. It is said in a revered book, "He that withholdeth corn, the people shall curse him;" and the instincts of humanity respond to that saying. But if it is wicked and accursed to "withhold" corn in times of scarcity, how much more infamous and criminal it must be to cause that scarcity, by artificial means, by the deliberate destruction of human food, and by the conversion of it into that which is not food, but which tends to promote disease, and to degrade the people, in the same proportion that it dissipates the resources of the nation, and perverts and frustrates the bountiful and beneficent intentions of Providence!"

Cooperative Stores; their Bearing on Athenæums, &c.
By the Rev. W. R. Thorburn, *M.A.*

After some remarks on the principle of cooperation—the advantages of the scheme, the salutary influence it exerts—the subject was illustrated by a reference to the *Bury Provision Society.* In March 1858, there were 280 members, capital £1346, and a dividend of £157. In March 1861, there were 1550 members, capital £9420, and a dividend of £1451.

The *phase* of the subject now submitted is *educational* or *literary*—an appendage of news-room, reading-room, and library, to these cooperative stores. This is a *new* and *influential element.* The Society referred to opened a news- and reading-room in October 1859. The source of income to this department is not subscription, but $2\frac{1}{2}$ per cent. on the net profits, yielding an average quarterly sum of £27. This sum is disposed of in these proportions:—£10 for the news-room and £17 for the library.

The influence which this *educational element* is fitted to exert on athenæums and mechanics institutions is great. They are dependent entirely on personal subscriptions. The *Bury Athenæum* had, in 1859, 628 members; now, in 1861, 431,—the decrease chiefly to be referred to this cause. The tendency of this phase of cooperation is to weaken or annihilate athenæums, and to bring about one of two issues, either to throw this department of education into the hands of working men, or to prompt the middle class to espouse cooperative institutions.

The Rev. W. Thorburn also read a paper, in which he deplored the effects of cooperative societies on Athenæums and other literary institutions.

On the Employment of Women in Workhouses. By Miss Twining.

The author commenced by saying that in 646 unions and workhouses in England and Wales there were on the 1st of January 113,507 inmates, of whom 30,654 were children in pauper schools. The whole number of indoor and outdoor poor was 850,896; and of those who were called able-bodied 40,000 were males, while above 110,000 were females. Thus a large proportion of our destitute pauper population was composed of women and children; in many workhouses they were two-thirds of the inmates. The returns of the Poor Law Board gave but scanty information; and with regard to particular workhouses, details were not published. The number of deaths in the course of the year might be ascertained from the reports of the local inspectors of health, but they found no details as to the ages and causes of death. Thus those who paid the rates, and ought to be interested in the mode of their expenditure, as well as in the welfare of those who were supported by them, knew nothing whatever about it. The one medical man who visited the workhouse, and the Guardians, were the only persons who knew anything about the state of things or the condition of the inmates. With a view of enlightening and interesting persons in these various large and important institutions, she would suggest that reports should be annually published, containing accounts of the numbers and classes of the inmates, the length of time they had been such, and, what would be the most important of all, the causes of death. This would give the information which now they had not, about the mortality of infants and children in workhouses, about which much was surmised, but little was known, from the impossibility of obtaining facts. In short, what she was anxious to urge was the admission of more daylight generally into workhouses, which would soon result from a more general interest in them. Subscribers to hospitals and other institutions wished to know how their money was spent, and what the management was; and why should not ratepayers wish to know what was done with the money they contributed? It was not only desirable but a positive duty to do so; and it was to be hoped that the interest, now partly awakened, might soon become more active and beneficial. The tide of sympathy and benevolence, which had reached to the very lowest and apparently to the most hopeless depths of the social system, could not fail to penetrate in time the recesses of our workhouses, where thousands of our poorest and most suffering fellow-creatures were maintained, but about whom so much ignorance and still more indifference prevailed. Here was one of the widest fields yet opened in our country for the exercise of woman's sympathy and help. Hitherto both had been practically ignored in these institutions, the management being entirely in the hands of the guardians, and frequently the only responsible woman in authority being the paid matron, who was expected to control and manage the house and all the inmates, however numerous they might be. It was now six years since Mrs. Jameson directed attention to the claims of women to an influence over persons of their own sex in institutions. Whatever the faults of the inmates of workhouses, they stood in need of woman's help and sympathy, probably all the more deeply because women only could be the reformers of their own sex; and if vice had directly or indirectly brought these women and children to the last refuge of the destitute, there was the more urgent call for those of their own sex to come forward to their rescue. This was the position taken by the Workhouse Visiting Society three years ago. During the Crimean war, hospital nurses were thought to be bad enough; but the workhouse nurses were almost invariably many grades lower still, because no remuneration was permitted for them. The most helpless cases failed to receive attention except through giving bribes to the nurses, who hovered around visitors to the patients in the hope of procuring gifts. The condition of the young was fully as important as that of the sick; and Miss Twining advocated the desirability of separating the decent and respectable girls and women from the corrupted and depraved—a point which had never yet been attended to as it deserved. The experience of nearly six months in the Industrial Home for young women opened by the Workhouse Visiting Society in London proved that a respectable place was needed for girls in the intervals of changing their situations. During that period 30 had been received, and from eleven workhouses alone. Of these 20 had been in pauper schools of some kind, and not having lost their character were not fit inmates of the wards in workhouses where women of all kinds congregated without distinction. One girl declared that she had never heard such language as greeted her ears in the ward of a London workhouse, to which she was transferred on leaving her place; and another girl, of 16, who proclaimed her intention of leaving the ward for the worst of purposes, said she had gained her information from women in the ward; and it was well known that the elder women, who were invariably the worst, took a pleasure in corrupting the minds of the younger ones. Guardians should have the power to pay for girls in institutions where there might be some hope of their remaining uncorrupted. At present there was no sufficient agency for doing this whilst they were in workhouses. The admission of a higher and better influence was the only hope of improvement that existed; and why such an agency should be so frequently rejected was surprising; for it was obvious that to improve the morality of the inmates was to enable them to lead a respectable life out of doors, and to get them off our hands. Yet this seemed to be entirely overlooked by the jealousy of some officials as to "interference," so called. She did not urge an indiscriminate and unauthorized admission of visitors to workhouses. That had never been the proposal of the Society to which she belonged. That might have caused confusion and inconvenience, which their plans had never done when properly carried out; they had always ministered comfort to the inmates, and contributed to the peace of the house.

On Strikes. By Dr. J. Watts.

Strikes, he said, were amongst the most serious evils to be encountered in the operations of trade; and he noticed the importance of a very intimate connexion between an employer and his workpeople. The pertinacity and endurance of workpeople on strike would do credit to a good cause, and was proof of their capacity for great improvement. He then passed in review some of the principal strikes that have recently taken place, most of which had arisen from dissatisfaction with the amount of wages paid or proposed to be paid. But strikes very seldom achieved the object sought; and it became their duty to inquire if, in the few cases where success was possible, that success could be equally secured without resort to this terrible engine of strife and suffering. Examples were then given of eight unsuccessful strikes, which represented the amount of wages lost at £1,082,650, profit lost £210,602, subscriptions £270,617, making a total of £1,563,869. All these strikes have terminated unsuccessfully; so that there has been no compensation for the loss. If these sacrifices were necessary, the endurance of the working-classes would command admiration; but he could not admit the justice or desirability of a restriction which prevents a parent and an employer from mutually arranging to bring up a youth to a good trade; he could not admit the wisdom of shutting out an efficient workman because he had not been apprenticed; nor could he see why any society should dictate the price of labour. With regard to the establishment of an arbitration court for the settlement of disputes, he suggested that it should be honorary, that the parties to the dispute should each name an equal number of jurymen, that the County Court judge for the district should be president or umpire, and that the business of the Court should be conducted without lawyers. A bill giving power to the Lords of the Treasury to arrange such courts on petition would restrict them within useful limits. Adverting to the establishment of cooperative societies and manufacturing companies with limited liability, he said the prospects they held out ought to stimulate prudential habits, and so improve the moral tone of working men. The operations of such societies would also supply a sort of wages barometer, showing what amount it is prudent to pay, because the conductors could have but small interest in paying too low a wage, since what is not paid in wages will be in profits, and the amount of profits declared would, in times of steady trade, also influence wages for the next half-year. If these societies prospered, we might see individual employers in self-defence constituting their workpeople partners in profits. But they had still to stand the test of "hard times," and they could not be expected to pass scatheless through a crisis. He concluded that strikes to restrict the number of workmen in a trade ought not to succeed, and that strikes against improved machinery were attempts to prevent the development of human intellect and the progress of civilization; and generally he concluded that strikes were wholly injurious, an entire waste of effort, to the extent of not less than a million of pounds sterling annually, or the bread of 38,460, with 4000 to 5000 additional who would be required by the profits lost through strikes. Improvements in the constitution of trade societies would, he thought, prevent many strikes, and would secure the support of employers for these societies; that cooperative societies, by teaching prudence, will be useful aids; and that an honorary and voluntary court of arbitration would amicably settle such disputes as might remain.

MECHANICAL SCIENCE.

Address of J. F. Bateman, *C.E., F.R.S., President of the Section.*

To those who favour us with their attendance for the first time, it may be sufficient to say that the object of the Section is the promotion of mechanical science in a wide sense; for to this Section also stands referred all questions of civil engineering, which, although they may in themselves be only remotely connected with mechanics, yet depend for their successful issue upon the proper application of mechanical knowledge. Indeed, it would be difficult to say to what material pursuit in life mechanical skill is not of primary importance. In Manchester especially this Section should be well supported; for in this district have been born or have resided some of the most distinguished projectors and inventors of the age—men whose ingenuity and labours have conferred incalculable benefit upon the world—such men as the Duke of Bridgewater, Sir Richard Arkwright, and Samuel Crompton, in days not long gone by, and whose places have been well filled by the inventors and mechanics of our own time. Amongst the questions which have recently attracted popular attention, and which are specially deserving of the consideration of the mechanical men of the day, are the improvements which are taking place in the construction of artillery, and in the antagonistic work of protecting the vessels of our navy from the terrible destruction to which they are exposed by the superior power and longer range of the guns which can now be brought to bear against them. It seems, at first sight, almost a matter of regret that our inventive faculties should be strained to the utmost to produce the most deadly weapon, and to ensure the most certain and extensive destruction of human life; but there is no axiom more true than that of a late great commander, that "the best security for peace is to be well prepared for war." On the subject of gunnery and ship-armour, we shall be fortunate in having the presence of many of those who have taken leading parts in their construction or improvement, and in the experimental and scientific investigations of these important questions; but I am sure that the Section will join me in the expression of deep regret that one amongst that number, second to none in mechanical skill, in successful results, and in indomitable perseverance, no less a man than that distinguished Manchester citizen, Mr. Whitworth, is prevented being here by serious illness. I trust it is only temporary, and that he will yet live many years to enjoy the profits and honours of successful enterprise. In the model-room, however, will be found one of his powerful and beautiful pieces of ordnance, and an armour-plate, four inches in thickness, pierced by the bolt discharged from his 12-pounder cannon. We are also to be favoured with some of the plates and other illustrations of the recent highly-important experiments at Shoeburyness, which, I trust, will be accompanied by explanations by our President, or by other members of the Association who have taken part in conducting these experiments. The respective merits of the various inventions which are now exciting attention, and the various modes of constructing ordnance and ship-armour will thus, I hope, be brought fairly and fully before the Section. The anxious attention of those most interested in the management of railways was, during the late very severe winter, when the thermometer fell in some places 10° or 12° below zero, unexpectedly directed to the sudden and numerous fractures in the tires of the wheels of the carriages and engines. The cause of these fractures, and the best mode of preventing similar occurrences in severe cold are matters of public importance, and fit subjects for notice and discussion in this Section. But serious as were the dangers resulting from the intense cold of last winter, they are as nothing to those which appear to attend the benefit of railway travelling by the excursion trains of the summer. Within the last few days we have been horrified by the accounts of two of the most disastrous accidents which have occurred in this country. As to the cause of one of these we have as yet but vague particulars. The other seems to have resulted from a failure in the working of the signals, and from a want of perfect understanding between two signalmen. Another subject which has recently attracted attention, through the terrible and disastrous conflagration in Tooley-street in London, is the extinction of fire. The powers which now exist for this purpose, with the methods which are adopted, would form useful topics for consideration; and such notices as will illustrate the most approved methods of prevention—whether by the adoption of plans of fireproof construction, or by the judicious application of water—could not fail to be both interesting and instructive. Manchester has fortunately been comparatively exempt from calamities of this nature; and there are peculiarities in the means adopted for their prevention which are deserving of attention. In those parts of this city in which protection against fire was most important, the dimensions and arrangements of the pipes were determined with special reference to these circumstances. In place of the old wood plug, a simple fire-cock, by which almost instantaneous communication could be made with the water in the pipe, and to which a hose and jet could be attached, was adopted, and the fire-engines were rather used as carriages or omnibuses for the conveyance of the firemen and their implements, than for actual use at a fire. Nearly every block of building in Manchester is commanded by at least a dozen fire-cocks within 100 yards. The question of the patent laws, and their bearing on the encouragement or discouragement of mechanical invention, will be prominently brought before the Section, and, I doubt not, very ably discussed by some of our most eminent men, who have specially considered the effect of protection. It is proposed to devote, if necessary, the whole of Friday to this important and interesting question. Many other matters of interest and importance will, I hope, be brought before the Section; and in the discussion that may arise on steam, on the best form of vessels, on the ventilation of coal mines, navigation, and the other subjects to which the papers before us promise to draw our attention, I trust we may all derive instruction and advantage, and find that the bringing together of people from all parts of the country for friendly discussion, and for the mutual interchange of knowledge, fully carries out the object of the Association for the Advancement of Science.

On the Patent Laws. *By* Sir W. G. Armstrong, *F.R.S.*

Several instances within the author's experience were referred to of the obstructive operation of the law which enables an individual, before he has put his invention into a practical form, to obtain a monopoly of the idea and then put a stop upon all others who are directing their attention to the same subject. The obstructive tendency of the Patent Laws is aggravated by the fact that, in addition to the patents which are legally valid, there is an enormous number incapable, if properly opposed, of being enforced at law, but to which people quietly submit in preference to troublesome and expensive litigation. This is a necessary consequence of the patents being indiscriminately granted to all applicants without investigation; and it would be difficult to remedy this evil by any practical preliminary inquiry. The number of patents, valid and invalid, is perfectly frightful; and it is impossible to make out with any certainty what one is at liberty to invent or use. The author pointed out the difference between copyright and patent-right: though both ought to protect the product of a man's mind, copyright neither created impediment nor injustice, while patent-right did both. It could not be disputed that the Patent Laws, in restricting the free use of ideas, obstructed invention, if, on the other hand, they encouraged it by holding out rewards. Thus the most that could be said was that they pulled opposite ways; and this could be no warrant to justify arbitrary interference with liberty of action. Although the Patent Laws ought to be discussed solely in reference to public policy, it would be harsh to exclude from consideration the interests of the inventor. He contended that as a rule an inventor would obtain sufficient reward without giving him exclusive rights. If the monopoly were withheld, the inventor got the start of all others; and the presumption was, that, understanding his subject better than others, he would keep the lead. The public have great faith in a name; and a reputation duly earned is not easily lost. Under any state of the law, hardships of inadequate reward must occur; and these cases he considered should be met by grants from the State. He instanced the inventor of the screw-propeller, who was unable to obtain any advantage from the law, whilst another person, who conceived the simple idea of enabling postage-stamps to be easily separated by punching a series of small holes between them, was placed in a position to obtain an exorbitant recompense from the Government.

The author, whilst he admitted that the law was capable of amelioration by having special tribunals for the grant and trial of patent-rights, compulsory licences, and the abolition of the right to patent foreign inventions, yet he regarded the whole system as unnecessary and impolitic, and could see no other complete remedy for its evils than its entire abolition.

Railway Accidents, from Trains running off the Rails. *By* G. Arnott, *M.D.*

Inasmuch as the *inertia* of moving bodies causes them to continue in a rectilinear direction, and when revolving in a circle this *inertia* produces what is termed centrifugal force, the flanges of the outer wheels of a locomotive, in rounding a curve, are by this force necessarily brought in contact with the outer elevated line of rail, the projections of the tires or flanges forming the chief resistance to their tendency to move off at a tangent. When in this relative position, however, should any disturbing force exist or arise, particularly one which produces a "jumping" or rebound of the moving body, such as will elevate the flange to the level of the rail, a catastrophe, if the train is going at ordinary speed, becomes inevitable.

Now, as the safety of the train so materially depends upon the flange, this should be considerably deepened, and the rails also, where necessary, in a corresponding degree. If a flange of ordinary depth is occasionally dangerous, one of double the depth, *of proportionate strength*, will prove in comparison more than doubly safe; and in case even of a defective condition of a sleeper or rail, the more powerful gripe of an enlarged flange will most materially lessen the risk of diversion.

On Elongated Projectiles for Rifled Fire-arms. By T. Aston.

After alluding to the improvements that have been made in war projectiles, which have resulted in the elongated form, he proceeded to notice the advantages which it possesses over the old spherical shape. The elongated projectile, presenting to the resisting atmosphere a sectional area considerably less than the spherical of the same weight, is less retarded in its progress through the air. It follows, therefore, that, although the spherical projectile with a similar charge of gunpowder is more easily set in motion, and has a greater initial velocity than the elongated form, and to that extent has at the outset an advantage, the elongated form is much better able to overcome the resistance of the atmosphere, and, owing to its superiority of momentum, preserves its progressive power for a much longer period; at the same time, it is less disturbed by the varying conditions of the elastic medium through which it is propelled. In short, it has a longer and truer flight. The essential condition to the efficiency of the long projectile is, that it shall move onwards with its point foremost; if it turns over in its path, it presents a large surface to the action of the air, its flight at once becomes irregular, and is rapidly retarded. The action of the common spinning-top suggests at once the idea that the best mode of making the elongated projectile move steadily through the air with its point foremost is to give it rotation round its axis of progression. The rapid revolution of the body causes its inherent inequalities to be rapidly carried round a constant axis in regular order, and a kind of balance is thereby established, which gives the body a steady motion. Various plans have been from time to time tried with the object of imparting to long projectiles a steady flight; they have been made with spiral grooves cut externally on their periphery, or internally from front to rear, in the expectation that the resisting action of the atmosphere acting on the inclined surfaces would give the requisite spinning motion. Again, they have been made very long and furnished with fins or feathers, in order that they may be propelled on the principle of the arrow, but no practically successful results have as yet brought projectiles of this kind into use. The required object is, as is well known, readily and successfully effected by propelling the elongated projectile from a rifled barrel, that is, a tube having its interior made of such a spiral form that the projectile while it is propelled from the breech to the muzzle is turned round its axis of progression: a rotatory motion is thus imparted, which is retained by the advancing projectile and gives it the required steady motion. The elongated bullet was first used with rifled small-arms, either poly-grooved or fluted, or, like the Enfield, having three grooves. The length, however, was limited; and various attempts were made to fire longer projectiles compounded of various metals and of various shapes, so that by changing the position of the centre of gravity they might be propelled point foremost. But, if made beyond a certain length, they were always found to turn over at moderately long ranges. Mr. Whitworth was the first to enunciate the principle that projectiles of any requisite length could be successfully fixed by giving them rapid velocity of rotation, which should be increased in proportion with their increased length. He, as is well known, uses rifles having a spiral polygonal bore, in which all the interior surfaces are made effective as rifling surfaces. The success of the elongated projectile having been established in the case of small-arms, their employment with ordnance followed as a natural consequence. Rifled ordnance were, therefore, called into existence to meet the requirements of the time. In fact, the rifled cannon may be considered as a rifled musket made with enlarged proportions. Directing our attention more particularly to the two systems of Armstrong and Whitworth, we see in the former the coiled barrel and fluted bore formerly used for the rifled small-arm, applied on an enlarged scale. In the Whitworth cannon the same system and form of rifling are used which are employed for the Whitworth musket. There is, however, a change required for the projectiles; they cannot, like the small-arms bullets, be made of lead, for obvious reasons, such as the cost of the metal, its liability to distortion of form, and unsuitableness for shells. Sir William Armstrong uses a compound projectile, formed of an iron case surrounded with a leaden coating—the rifling being effected by the force of the explosion in the barrel, which is thus partly expended in forcing the lead through the grooves. Mr. Whitworth uses a simple hard-metal projectile, made of the requisite shape to fit the rifled bore by machine labour in the manufactory; so that the whole force of the explosion is employed to propel the projectile. After giving a description of the two projectiles, and pointing out that the Armstrong projectile necessarily required a breech-loading cannon, and that the Whitworth is used at pleasure for muzzle-loading or breech-loading cannon, Mr. Aston proceeded to notice the external shape of the projectiles. The importance of giving to ships intended for high speed the shape best suited to facilitate their progress though water is now universally acknowledged; and Mr. Whitworth considered that it was necessary to ascertain, by reasoning upon similar grounds, and by experimental research, what was the proper shape to give to his projectile, so that it might be propelled through the air under conditions most favourable to precision and range. He, after numerous corroborating experiments, decided that the projectile of the form exhibited to the Meeting was the best. It has a taper front, having nearly the external section of what mathematicians term the solid of least resistance, the curve being somewhat rounded; the rear is made to taper in such proportion that the air displaced by the front is allowed readily to close in behind upon the inclined surfaces of the rear part. The middle part is left parallel to the required distance, to provide rifling surfaces and obviate windage. The results of long and repeated trials show that this form of projectile gives much greater precision and a superiority of range, varying from 15 to 25 and 30 per cent. (according to the elevation and consequent length of range), as compared with a projectile of the common rounded front and parallel rear end. At low elevations, where the range is comparatively short and the velocities great, the difference in the result of the taper and non-taper rear is not so marked as at the higher elevations, where the mean velocities of the projectiles are reduced. But at all ranges the superiority exists both in precision and velocity, as the elongated projectile at no practical range has a mean velocity so great as to prevent the atmosphere closing in behind it. One of the most important advantages attending the use of the taper rear is, that it gives a lower trajectory, which renders errors in judging distance of minor importance, as the projectile which skims along near to the ground is more likely to hit a mark, especially a moving one, than a projectile which, moving in a more curved path, has to drop, as it were, upon the object aimed at, whose distance therefore must be accurately guessed. The taper shape of the rear is peculiarly well adapted for the proper lubrication of the gun, which is most essential for good shooting. With the Whitworth gun a wad made wholly of lubricating material was introduced; it obviates the necessity of washing out the piece,—and the subsequent adoption of a similar wad for the Armstrong gun enabled that piece also to be used without washing out, which was at first necessary and found to be a very inconvenient operation for a service gun. Various forms of elongated Whitworth projectiles suited for special purposes were described: tubular projectiles for cutting cores out of soft materials, as the sides of timber ships; flat-fronted hardened projectiles, first used by Whitworth and afterwards by Armstrong, for penetrating iron plates. It is found that these projectiles penetrate, when fired point blank, through iron plates inclined at an angle of $57\frac{1}{2}°$ to the perpendicular. The edge of the flat front, though slightly rounded, takes a hold, as it were, as soon as it touches the plate, and the resistance met is merely that due to the thickness of plate measured diagonally. Official experimental trials made on board the 'Excellent,' at Portsmouth showed that these projectiles penetrate readily through water, and would go through a ship's side below water-mark. The new American floating battery, which is submerged to protect her sides during action, would find no defence in that plan against these projectiles. Shell and shrapnel having the elongated form and taper rear were also described; and to show the suitableness of that form for ricochet firing, tables were read, from which it appears that the mean results of a series of six shots, making many ricochets within a range of 2400 yards, gave the greatest mean deviation of about 75 yards from the straight line. In considering the probable result of the contest now going on between armour-plates and projectiles, it should be borne in mind that the limit of thickness of armour-plate that can be carried by ships will soon be reached, but that the power of destruction of projectiles may be without doubt increased far beyond what has hitherto been tried. It may therefore be reasonably anticipated that in this all-important contest the victory will ultimately rest on the side of the projectile.

On Street-Pipe Arrangements for Extinguishing Fires. By J. F. Bateman, *F.R.S., President of the Section.*

He had hoped that a paper would have been read on this subject by Mr. Rose, of the Manchester Fire Brigade; but as that gentleman had been called away by the illness of a relative, he thought it right that the proceedings of the Section should not terminate without some observations being made on the subject. Nothing could have been much worse than the arrangements made for the extinction of fires some fifteen years ago, nor than the state of things which existed at the present day in the City of London. In most large towns, as Manchester and Glasgow, for instance, where the supply of water had been taken into the hands of the Corporation, the best preparations had been made for the extinction of fires. But in London the fire-engines and the fire brigade were maintained by contributions from the different insurance companies; and therefore it was evident that their interest only lay in preventing the destruction of property that was insured. It was clear this was a state of things which ought not to exist in this country. Some twelve or fifteen years ago he turned his attention to the subject of the extinction of fires. The old wooden plug was then generally in use, and it still continued in use in some parts of the country. Mr. Bateman described the construction of the fire-cock and stand-pipe, with which he had replaced the old plugs in Manchester and other towns, and stated that, as a general rule, these fire-cocks had been found sufficient without the use of fire-engines. He also explained the principle upon which the water-pipes were laid down in Manchester; so that within reach of nearly every block of valuable buildings in Manchester and the neighbourhood, there were from two to three sources of water-supply from different water-mains, and ten or twelve fire-cocks within a hundred yards. Then came the question of pressure. About eighty or ninety feet was the greatest height water could be thrown by a fire-engine. The highest mills in Manchester were from forty feet to sixty feet; and experiments had been made which showed that water could be thrown without the aid of fire-engines from thirty-three to ninety feet in height, according to the pressure in the pipes, during the day, and when the service of the town was fully going on.

On the Applications of the Hydraulic Press. By Edward T. Bellhouse.

He traced its origin to Joseph Bramah, in 1785, and explained its present construction by means of diagrams, and then adverted to the various purposes to which it has been and is applied. These included the raising of the Britannia tubes, the launching of the 'Great Eastern,' the raising of ships on slips, the packing into bales of Manchester goods, cotton, wool, and hay, the extraction of oil from linseed, rapeseed, and hempseed, the manufacture of lead pipes, the testing the strength of materials, &c. The application of the steam-engine for working the pumps was alluded to, as now becoming general. He more particularly dwelt upon the various kinds of hydraulic presses used for packing cotton in India. He also described a stop and let-off cock, worked by a hand lever, which was very convenient of application. In the cotton-press, the pressure put upon the pumps was sometimes as great as six tons per square inch. He hoped some lighter and stronger metal would be found for the cylinders, rams, &c. than the cast iron at present used.

On Artillery versus *Armour. By* Captain Blakely.

The author said it was now four years since he first laid before the British Association at Dublin his ideas with reference to the strength and extent of range which might be obtained with cannon built up of concentric tubes of metal, so adjusted that all should share in resisting the bursting effort of the charge of gunpowder. The size of cannon before the discovery of this method was limited by the certainty that any smooth-bored gun above the 68-pounder, and any rifled gun of even half that size must burst after very few rounds with full charge of powder. Now, Captain Blakely maintained, there was no difficulty in making guns ten times more powerful. He believed that not only a 600-pounder, but even a 6000-pounder could be constructed, if great care were taken in selecting the best materials, and in putting on the outer layers with the exact degree of tension required to enable them to exert their strength. If the outer layers (he used them generally in the form of rings) were too tight, they burst before the central part; and if they were too loose, the central parts burst first, and perhaps left the rings whole. Extensive experiments had been made to determine the proper degree of tension for these rings, because on that point depended the efficiency of the gun. Not only had he (Captain Blakely) made such experiments, but also the Spanish and English Governments,—the latter having made several hundred full-sized cannon, some of which were built up entirely of iron, the tension of the outer portion being varied—some being constructed partly of iron, partly of brass. It was well worth the trouble of any person desirous of studying the question to visit Woolwich Arsenal and see the broken fragments of these cannon. Captain Blakely believed the truth might have been arrived at with less expense; however, the result was the acknowledgment by the Select Ordnance Committee of the exactness of Captain Blakely's views in reference to cannon, viz. that all large guns must be built up, that the outer parts must be in a state of initial tension, and that so definite, that the slightest excess or deficiency of tension detracts from the strength of the gun. All guns now made in the English Arsenals are constructed on those principles—though afterwards spoilt, in his opinion, by the weakening of the breech for the purpose of loading by that end. Spanish guns also are now built up. Captain Blakely exhibited the drawing of the new Spanish naval gun, and explained its construction. The diameter of the bore was between six and seven inches; more than half of the gun, he said, was of cast iron, the upper portion of the breech only being formed of rings of steel.

Captain Blakely regretted that the English Government did not obtain all the advantages from the system which he thought it capable of affording. They refused to make any cannon larger than 120-pounders—perhaps because Sir William Armstrong's breech-loading apparatus was not adapted for large guns; and they also refused his (Captain Blakely's) offer to make at his own expense a 600-pounder, and lend it to them for experiment against their model targets. He would not say anything of the policy of this conduct, but he believed he was in order in saying that it was not "philosophical" to refuse to try a larger gun, and at the same time to proclaim that the plates, constructed to resist little 100-pound pop-guns, were "impenetrable." For his part he firmly believed that he could make cannon either to punch holes through not only 4-inch but 8-inch plates, or, what was better still, to crush them completely.

On Recent Improvements in Cotton-Gins.

By David Chadwick, *F.S.S., of the Manchester Committee.*

A description was given of the old Indian churka, one of which was exhibited to the Meeting; and the invention of the American saw gin, by Eli Whitney, was also noticed and described. On the recent visit to England of Dr. Forbes, the superintendent of the cotton-gin factory of the late East India Company, to Darwhar, he introduced an improved cotton-gin, based upon the principle of the Indian churka. This churka gin had subsequently been improved by Mr. John Dunlop, of Manchester, and Messrs. Platt Brothers, of Oldham; and the improved machines were exhibited to the Meeting. The improvements in Messrs. Platt's machines consisted in the application of spike rollers revolving at different speeds in connexion with vibrating machinery, which transmits the cotton to the ordinary churka rollers. The effect of this is to enable the machine to be supplied with cotton continuously instead of at intervals with the fingers. The machine is intended to be worked by power, and requires the attendance only of a child thirteen years of age. Mr. Dunlop's machine was less expensive, but more compact, and bearing a closer resemblance to the original churka, and was intended to be worked by hand.

A Proposal for a Class of Gunboats capable of engaging Armour-plated Ships at Sea, accompanied with Suggestions for fastening on Armour-Plates. By Dr. Eddy.

The author thought that the monster iron-clad vessels which we and our neighbours were building might be successfully assailed by vessels of very inferior size specially designed for the purpose. The first essential condition for such vessels was superiority of speed, with such protection as to approach the enemy without being crippled. He believed that one such vessel with a couple of heavy guns might so harass a larger vessel as to paralyze her movements, and that two such vessels might even engage with advantage; and, if this was so, might not a flotilla of these small vessels advantageously engage a fleet of the large iron-plated ships? To obtain superior speed, we must either sacrifice weight of metal or increase the size. He preferred the former, and by reducing the armament to a very few guns (two or four), and those of the powerful kind now manufactured, he thought we might obtain the required speed within moderate dimensions; and he hoped to show that, by a peculiar adjustment of material, we might gain all the protection required, without immoderate weight. Much of this problem had indeed been worked out by Capt. Coles, of whose cupola, the conical fort, with revolving shield, in the model produced, was a modification. A speed of sixteen knots an hour would, he believed, be sufficient for present purposes, and he took it that this speed might be secured without difficulty in a vessel of fine lines, and of certain proportions, without tremendous size. Dr. Eddy proceeded to describe from a model the kind of gunboat he proposed to build. The dimensions, he said, were calculated from one datum, namely, the least elevation above water at which the guns could advantageously be laid, which he took to be 8 feet. In this position, then, he would place two of the heaviest Armstrong guns, with their muzzles $4\frac{1}{2}$ feet apart, on an inclined slide, upon a turn-table placed within a fixed conical fort, armour-clad, the sides of which sloped at an angle of 45°. Above this, for a perpendicular height of 4 feet, he would protect the guns and gunners with a shield of iron plate, also at an angle of 45°. The shape of the fort would be a truncated cone on a cylinder, like an extinguisher upon a candlestick. A second cupola he believed might be added, and this would give an armament of four guns, which, if concentrated upon one point at short range, must have a crushing effect. But, to be of any use, the smaller vessel must be enabled to approach her large antagonist without risk of having a shot sent through her bottom from the enemy's depressed guns. The manner in which he proposed to fortify the gunboat was by keeping all the vital parts well below the water-line, and covering them with a deck which would deflect upwards any shot that might reach it. As the boat was only intended to attack ships, not forts, he presumed there was no need to apprehend a shot striking her at a larger angle with the horizon than 7°. Still at this angle, to protect the sides of the vessel effectually, the armour must be carried at least 4 feet above water and 3 feet below, possibly more; but as this involved a weight of 300 tons in plating alone, some other method of protection must be sought. He hoped he had found this desideratum in a plan which aimed at carrying out thoroughly the principle of deflection. His plan consisted of an arched deck of inch iron resting upon two courses of timber, the extremities of the arch being tied, so as to neutralize the outward thrust. He proposed that this should spring at the sides from 3 feet below the water-line, and that the crown should rise amidships up to the water-line, the crown being kept tolerably flat—the object being to present so small an angle that even a flat-headed bolt should glance off. The space above the deck and between it and the water-line he proposed to pack with some tough and resilient but light fibre, and these qualities he found combined in the cocoa-nut fibre, which could be easily rendered incombustible by sal-ammoniac. This fibre would offer a considerable amount of resistance to the penetration of a shot, and in proportion to the resistance would tend to deflect the shot. The exact amount of resistance which this mode of packing would afford could not be ascertained without experiment, but the trial would not be expensive. He might be met with the objection, that steel or iron was the substance which offered the greatest amount of protection proportionate to its weight. Granting this, he maintained that there were circumstances under which iron alone could not be advantageously used, and that this was one. Dr. Eddy alluded to the difficulty now felt in securing the iron plates on the sides of the vessels without weakening them by perforating holes; and he mentioned a plan of screwing the plates within a rail-shaped frame, which he said he had been encouraged by Mr. Fairbairn to lay before the Section, and which he thought would obviate the difficulty.

On a Brick-making Machine. *By* PETER EFFERTZ.

On a Perambulator and Street Railway. *By* JOHN HAWORTH.

The author proposed a central rail, having in it a groove for a small guiding wheel, similar to that of a perambulator. By this simple contrivance, an omnibus could be kept upon the two outer and level rails without the necessity of flanges to the wheels. The plan was cheap beyond comparison, costing only £1000 per mile. A length of route had been laid down in Salford for some months, and had given great satisfaction; it had been ridden upon by many persons, engineers and others, who found it to be practicable and agreeable. It required 35 per cent. less power to draw an omnibus over metal rails than the ordinary roads, and it was estimated that there would be a saving in the wear and tear of vehicles of 75 per cent. He believed it would be to the interest of trustees of roads to lay down such a railway, as it would save the great destruction of the roads; and coach proprietors would be glad of the opportunity to pay a mileage toll for the saving of horses and rolling stock which they would realize by the change.

On the Rise and Progress of Clipper and Steam Navigation on the Coasts and Rivers of China and India.—Section 1. *By* ANDREW HENDERSON, *A.I.C.E., F.R.G.S.*

1. The importance of this subject is too great to need any comment in bringing it before the British Association. It is owing to the superiority of her navigation that England is chiefly indebted for her supremacy amongst other nations; and it is by that means alone she can hope to maintain her dominion. Any subject, therefore, that bears at all on the question of navigation is of too great moment to be passed over without the fullest consideration of its value and applicability.

2. The author's system of steam communication is more immediately connected with India and China, as it is in those countries that he has spent many years, the navigation of which he is intimately connected with, and to its improvement he has devoted the best energies of his life. The navigation of the Eastern rivers, coasts, and archipelagos is perhaps the most difficult and dangerous nautical service in the world. Any plan, therefore, which will successfully overcome those difficulties must be considered as one of universal application.

3. The vast interest at stake in those countries is too great for any plan to be neglected which would tend to preserve them to us, and the recent Indian mutiny shows the urgent necessity for maintaining a perfect communication throughout the coasts and rivers of British India, extending, as it does, from Kurrachee to Singapore.

4. The river system, at present navigable from Peshawaur to Sudiya, on the Indus and Burhampootra, would, if navigated on its upper affluents by light-draught boats, bring European civilization and science in communication with 250,000,000 of the population of India.

5. The recent opening of the ports, rivers, canals, and lakes of China gives a larger field for enterprise in that country than was ever before anticipated. Having visited China since 1817, the author has always held the opinion that China has, for ages, established the best system of river navigation in the world, both in the construction of boats to meet the requirements of trade, and in her canal work, to which may be attributed her early civilization and the means of supporting a dense population of 360 millions.

6. He purposed, therefore, giving a brief review of the principal systems which

have been established on the Bengal and Scinde rivers, with the results attained by each, together with his proposal for a better system than has yet been adopted, and its extension to India and China. His plans, modifications, and improvements are applicable to all the vessels in use, and consist of an embodiment of the best features of each type derived from thirty years' practical experience and close observation of the navigation of the coasts and rivers of India and China, and other parts of the world.

7. The papers presented by the author on this occasion were the result of considerable labour, and were in continuation of former reports made to the Association, viz. "Report on the statistics of life-boats and fishing-boats," published in the Association's Report, vol. 1857; also as a member and contributor to the "Report of a Committee, consisting of the Right Hon. Earl of Hardwicke, chairman, Mr. John Scott Russell, Mr. James Robert Napier, Mr. Charles Atherton, Rev. Dr. Woolley, Admiral Moorsom, Professor Bennett Woodcroft, and others, 'appointed to inquire into 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.'"

8. Early in 1858 the author brought before the Indian government a review of steam navigation in the Bengal rivers, together with a plan to construct a fleet of steam tug- and tow-boats, to meet the military requirements of government, and form the nucleus of a system of water-transport service on the Ganges, Burhampootra, and Irrawaddy. Subsequently he submitted a plan of a Military Nautilus Flotilla of one tug- and three tow-boats, 100 feet long, with engines of 40 horse-power in tug, and auxiliary power in each tow, built at an estimate cost of £6000 to £8000;—for the smaller boats, 75 feet long and 50 tons, with engines of 20-horse power, £5000 to £6500. At the close of the session of Parliament he proposed to an eminent engineer that, if he would provide the engine, he (the author) would build the hull and fittings of a military nautilus—a proposition which was declined.

9. In 1858 the subject was brought before the British Association, and is printed in the Reports of 1858, entitled, "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." Copies of the report have been circulated among the members previous to the discussion of the several subjects contained in the two papers—that on the system of tug- and tow-boats comprising a record of the experiments I have made with the smallest Nautilus flotilla during the last two years, including the resistance as measured by dynamometer.

10. At the Mechanics' Institution, David Street, the NAUTILUS FLOTILLA SYSTEM was exemplified by models, on half-inch scale, of the smallest class of Nautilus flotilla, of one tug- and two tow-boats, 85 feet long each, and 50 sailing and cargo boats, built for the East Indian Railway Company, on the author's lines, and 'Assam' type, as iron oulacs and bhurs of the Bengal rivers; half, or twenty-five iron oulacs, being built on his specification, and mercantile system of contracting, with details of Chinese rig, fitting, and sculls, with his patent balanced rudders in bow and stern.

11. Also, on a quarter-inch scale, the models of a first-class Nautilus flotilla, of one steam-tug and two auxiliary tow-vessels, each 200 feet long, on the author's lines, of the 'Assam' type, but on the routine or lump-sum system of contracting, for the East Indian Railway Company; their consulting engineer furnishing the specification and construction—that of the contractors being deficient in strength and proportion. Six of these vessels and three steam-tugs of 170 horse-power have been built with his patent balanced rudder, bow and stern.

12. These vessels are all built on the type of the 'Assam,' with engines of 100 horse-power by Fawcett and Co., of Liverpool, a model of which was exhibited to the Association, showing the bow and stern rudder as originally fitted, and used for one year on the Burhampootra, when she was transferred to the Ganges, and, from the prejudice of commanders, fitted with the Ganges rudder, where, without alteration in the engines, rovers, or vessel, after twenty years' service, she is now (1861) being lengthened.

13. The second portion of these papers is a continuation of the "Report of the Committee on Shipping Statistics, presented to the British Association, September 1858:—Report of the Committee appointed by the British Association to inquire

into the statistics of shipping, with a view to rendering statistical record more available as data conducive to the improvement of naval architecture as respects the adaptation of the form of ships to the requirements of sea-service."

14. Mr. Atherton has already made a report showing that, by a little variation in the shape of the ship, as great a difference may be made in the freight of goods carried by her (that is, her actual mercantile value) as there is between 100 and 102.

15. In continuation of the report on shipping statistics, the author has devoted his attention to reducing the amount of capital required, by the adoption of a mercantile system of contracting, and the establishment of a system of test-trials through tabular forms, and a register of particulars of all vessels.

16. The author presented a tabular register for all the river steamers in the Indian Government, and private, railway and guaranteed companies in India. The particulars for register are obtained from three tabular forms of record, return, and report of trials. There is an abstract of correspondence with the East Indian Government, in reference to the establishing improved steam tug- and tow-boats of the 'Assam' type on the rivers of India and China, in the left column.

17. In the right-hand column is an abstract of correspondence with Sir James Melville, K.C.B., official director of Indian railways (guaranteed), with a memorandum on the test-trials of steamers, proposing to adopt a uniform mode of recording the dimensions, calculated quantities of displacement, and capability for cargo. There are also rules for testing the strength and capability.

18. An instance is given of the trial of barges that proved deficient in strength, and of a trial steamer and tow-barge of another contractor that averaged $11\frac{1}{4}$ miles an hour, carrying 600 tons of cargo, and a 4ft. draught, for a three hours' run, half of which time was with a throttle-valve full open, to test the efficiency of the boiler to maintain the steam at the contract pressure.

19. The tabular forms presented were as follows:—Record of steamers, form A: Construction; form of tender or certificate of dimensions and calculated quantities of displacement; area of mid-section; weight of hull, engines, and stores; showing the draught of water, resistance, and capability for cargo; also the cost or capital per ton.

20. Return, form B: The particulars of vessels and engines, with record of experimental trips and performances at sea, and consumption of coal.

21. Report, form C: The same particulars on test-trials, with diagrams to indicate horse-power.

22. These forms of return and report are similar to those used by the Admiralty, and, with the record of steamers for May, a register may be formed of the particulars of dimensions, calculated quantities of displacement, area, mid-section, weight of hull, engine, stores, and draught, such as will enable a register to be formed of all vessels, so that their coefficiency may be calculated.

Section 2.—*Reproposals for a General System of Tug- and Tow-Boats of the Native Type.*

The steamer 'Forbes,' with engines of 120 horse-power, by Bolton and Watt, similar to the 'Soho,' was built and commanded by me, and after establishing her as a tug vessel at Calcutta in 1830, I proposed and carried out the project of towing a ship to China, 3000 miles, half of it against the monsoon, carrying a cargo of opium in advance of sailing vessels. This river-steamer was fitted for sea in one week after the arrival of the 'Jemasina,' a ship of 380 tons, which she towed; she was fitted with false sides, which increased her breadth three feet, and also with Chinese masts, and had an addition to her funnel. The photograph which accompanied the paper shows her as she arrived at Lintin, the outer anchorage of the port of Canton. In India, the first river-tug for sea-service was fitted with Chinese masts and sails, like a Chinese junk.

The lithograph plan in red, Appendix B, which also accompanied the paper, comprised comparative plans and sections of all the river-steamers, tugs, and tow-barges, trains and flotillas that have been built, tried, and improved, so far as is known from the published accounts, since 1858.

The first are those of the East Indian Railway Company, on the Bengal system of tug- and tow-boats of similar size.

2ndly. The Indus Flotilla Company's steamer 'Stanley,' on the European system of spoon-ended bow and stern. Also the large steamer, 360 feet long, recommended by the Commission who visited the Rhone.

3rdly. The Oriental Inland Company's train of articulated barges (Bourne's patent), consisting of one steamer and five barges, which may be called the theoretic system of river navigation on the punt type.

4thly. The Nautilus Flotilla system of tug- and tow-boats, giving sheer and deck plans of one tug- and three tow-boats of the 'Assam type,' as originally tried on the Thames, and of a steamer and two tow-boats as adopted from experience, and now ready for further trials.

There are shown also the East Indian Railway Company's vessels, the 'Ganges' and 'Excelsior,' two large vessels built in Calcutta, and provided with locomotive engines, with some particulars of their capability and fittings. Also the midship sections of four steamers built on my lines and fittings, the last of which, the 'Sir James Melville,' sailed out to India with a false bottom, as proposed by me. As to small boats, there are plans of the 'Surprise,' 85 feet long, towing two barges of similar dimensions alongside. She has been extremely useful, and affords also a fair contrast with the 'Assam Nautilus,' the one being 90 and the other 20 horse-power.

Reference to Appendix B gives particulars of the East Indian Railway Company's fleet of ten steamers and barges; also the result of the trial of Messrs. Vernon and Sons' barges as to strength, which necessitated an additional strength of girder equivalent to one-fifth, the vessel being reduced in length 25 feet, and the weight added to the girders; two of the spoon-ended barges being reduced to 200 feet, the bow of the fifth forming the stern of the sixth, with new bows of the 'Assam' type fitted to each, on plans furnished by me.

Of the test-trials of Messrs. Stevenson's trial steamer and barge, the result is given in a tabular form, at a light draught of steamer, at medium, and load draught; of steamer and barge loaded to four feet, carrying 600 tons of cargo, with engines of 596 I.H.P., at a speed of $11\frac{1}{4}$ miles per hour.

The East Indian Railway Company's fleet consists of ten large steamers and tow-barges, employing a capital of about £250,000, with a boat establishment of three small steamers, twelve large barges, 150 iron flats and cargo boats, averaging 90 feet, and 200 or 300 iron and timber boats and oulacs, built in Bengal, besides the 50 sailing boats or iron oulacs, built on the Thames, on my plan of Nautilus Flotilla system and 'Assam' type, at a cost of £29,925, or £600 each, completed in Calcutta.

Thus £600,000, a capital guaranteed for railway purposes, has been invested by the East Indian Railway Company in a fleet of large steamers and barges and small steamers and boats, established for the conveyance of materials during the construction of the line.

The Indus Flotilla Company.—The 'Stanley' experimental steamer (a sheer plan of which is shown in the Plate, Appendix B, No. 1 and 2) gives the results of her trials on the Thames in 1838, as shown in tabular form: she required nearly 10 indicated horse-power to one square foot, mid section, to attain a speed of thirteen miles an hour, without cargo or tow-boat, while the East Indian Railway Company's trial steamer and barge, tried in June 1859, with only 3 horse-power, attained a speed of $11\frac{1}{4}$ miles an hour, carrying 600 tons of cargo—a practical test of relative efficiency as to speed and capability for cargo of the 'Stanley.' The difficulty of steering and towing on the Thames induced the addition of $12\frac{1}{2}$ feet to the stern as a fender to the rudder, with a stage for steering as shown in plan.

The flotilla of steamers, barges, tugs, and cargo boats were contracted for in this country in 1858, besides the 'Stanley,' six other passenger steamers, seven accommodation flats, also thirty-three cargo barges, and six tug steamers 100 feet long, with engines 30 horse-power, built of corrugated iron. I find by an extract from 'The Engineer' of the 23rd of August, that the 'Stanley,' after a great many alterations in engines and paddles, is still inefficient, and is now (July 1861) laid up awaiting a new cylinder. Of the six passenger steamers it was stated that only one had been partially tried, when it was found that the tubular boilers were inefficient, owing to priming; and of the small tug-boats only two were in use, and were unable to tow the number of barges built for them. The above facts prove the necessity for having thorough test-trials and improvements in this country before sending vessels to India; and it may be fairly estimated that it would require 10 per cent. of the capital of £50,000 to place the seven large steamers and barges in an efficient state for service. If £10,000 had been spent in this country on trials, it would have saved this expense and delay.

With respect to the six small tug and thirty-three corrugated tow-boats, some experiments were made on the Mersey in 1859, when I expressed to Sir James Melville great doubt as to their power of tugging strength and durability, and which has been verified by the accounts received in 1861. On that occasion I strongly urged test-trials of the 'Assam Nautilus,' to test the capability of the small boats; and there can be no doubt that if 10 per cent. had been spent in trials in this country, they would have had efficient vessels as feeders to their line early in 1860.

The capital invested is £500,000, the interest guaranteed by the Government of India to the Indus Flotilla Company, which has constructed its vessels on the European system and spoon-ended type of build, contracted for on the railway or speculative system adverted to in my review and letters to the Council in 1859.

From the experience of the last three years, it is a matter of consideration whether the revenues of India will not be burdened with the interest of the capital for many years to come.

The Oriental Inland Steam Company, on Bourne's Patent Train of Articulated Barges on the Punt Type.—The plan, and page 1 of Appendix B, show the deck plan of the 'Train Indus' steamer, 200 feet long and 100 H. P., towing four barges 300 feet long, built and tried at Kurrachee, realizing a speed of 5·23 miles with four barges, and 8·56 miles with one. Passing to the Indus, the steamer was sunk, by collision with the 40-feet barge; the experimental trials costing £15,000 in India. The steamer 'Sutlej' and one barge were lengthened 30 feet, and provided with rudders, and are now employed towing astern in the usual way.

The 'Jumna' (No. 4 plan) shows the alterations resulting from an expenditure of £34,000 on trials in India and England, which consist of the addition of two side rudders to the steamer, and four barges additional to the length of stern; for the adoption of balanced rudder, and finer lines to bow; with an engine and screw to act as bow rudder.

At a preliminary trial of the barges made on the Clyde, 26th September, the speed varied from 6½ knots, with five barges articulated together, to 9¾ knots with one barge, towed by the Clyde steamer 'Ruby,' of 100 N.H.P., working up to nearly 800 Ind. H. P.

At the request of the Directors, I was present at that trial, and made some experiments with the dynamometer, of which a copy will be furnished. I then visited the 'Jumna,' at Liverpool, at their request, and there obtained much information from the engineer and late officers of the steamer 'Ganges,' which had foundered on the voyage to Calcutta, and will be referred to afterwards.

[The author also presented other papers under the following heads:—"A Statistical Record and Return of Experimental Trials here, and Performance in India."—"On Contracting for Building and Fitting River Steamers for India; with Observations and Improvements."—"Observations on Steering and Towing, with Improvements resulting from Trials and Practical Experiments."—"On the Fitting and Rigging of River Steamers for Sea Service, and of Vessels suitable for both."]

On a Sledge Railway Break. *By* James Higgin.

The author referred to the imperfect action of the ordinary railway breaks for checking a train on the first warning of danger. His plan consisted not of merely stopping the revolution of the wheels, but of placing under the carriages, over the rails, a lattice framework of iron, whose under surface, for a foot in breadth, resembled a sledge. This sledge plate (about 16 ft. long on each side) reached down to within about 4 inches of the rails, and by half a turn of an eccentric actuated by a rod stretching under the carriages from the locomotive and worked by steam, the carriages were instantly lowered and began to slide. In the case of axles breaking, the "sledge" arrangement would also afford support. The main advantage claimed for the sledge break was, that the increased length of surface presented to the rails obviates the jarring, dislocating and shaking which ensue when the wheels are suddenly locked at a high rate of speed. Its application by steam power and complete control by the engineer also ensure its instant application when needed; and the wheels will last longer from being spared the friction of the breaks and rails. But the result of these advantages combined being to enable a train to be brought to a stop in a much shorter distance than is now effected, was the most striking benefit anticipated from its introduction.

On Photozincography, by means of which Photographic Copies of the Ordnance Maps are chiefly multiplied, either on their original or on a reduced or enlarged scale. *By* Colonel Sir HENRY JAMES, *R.E., F.R.S.*

The process is applicable to the reproduction of old manuscripts and old printed books, and any line engraving. A copy of Domesday Book (the part relating to Cornwall taken by this means) was exhibited to the Meeting. The process consists in taking a photographic collodion negative, which is intensified by means of bichloride of mercury and hydrosulphuret of ammonia. Paper, deprived of its size, is saturated with a solution of gelatine and bichromate of potash. The paper thus prepared is exposed to the light beneath the negative, the result of which is that the parts which have been exposed to the light become insoluble. The whole is then inked with a greasy ink and afterwards washed in water, which removes the ink from all the parts except those on which the light has acted. A transfer to stone or zinc is then taken in the ordinary way, and copies are printed. The author then described an improvement which had lately been made in the process, by means of which a reduced copy of a map or plan could be made, in which the minor details (which would be useless on a reduced scale) could be omitted, and the names of places and other features of the plan given in full-sized legible characters.

On the Application of the Direct-Action Principle. *By* W. B. JOHNSON.

The author said that whilst immense improvements had been made in almost every other class of machinery, the stationary beam-engine remained almost in the same state as when it left the hands of the earliest makers, and may consequently be regarded as one of the most imperfect pieces of mechanism of the present day. Comparing the beam with the direct-action engine, he said the latter are superior in the following points: viz., they are independent of the foundation and engine-room walls for strength and support; they are less liable to derangement and breakage, and such cases are attended with less serious results; offering also great advantages in the accessibility to the condensing apparatus and all other working parts of the engine.

On Patents considered Internationally. *By* R. A. MACFIE.

On the Resistance of Ships. *By* Professor W. J. MACQUORN RANKINE, *F.R.S.*

The author states that the investigation to which this paper relates was founded originally on experimental data supplied to him by Mr. James R. Napier in 1857, and that its results were successfully applied to practice in 1858 and subsequently, to calculate beforehand the engine-power required to drive at given speeds ships built by Mr. J. R. Napier. He refers to previous investigations of the effect of friction in resisting the motion of a ship through the water; but remarks that those investigations could not be expected to yield definite results, because in them the velocity of sliding of the particles of water over the ship's bottom was treated as sensibly equal to the speed of the ship; whereas that velocity must vary at different points of the ship's bottom, in a manner depending on the positions of those points and the figure of the ship, being on an average greater than the speed of the ship in a proportion increasing with the fulness of the ship's lines. He then explains the general nature of the mathematical processes by which the friction can be determined. Their results, in the exact form, are very complex; but they can be expressed approximately, for practical purposes, by comparatively simple rules. Examples are given of the application of those rules to experiments by Mr. J. R. Napier, the author, and others, on steam-ships of very various sizes, forms, and speed.

The principal conclusions arrived at are:—that friction constitutes the most important part, if not the whole, of the resistance to the motion of ships that are well formed for speed; that its amount can be deduced with great precision from the form of the ship, by proper mathematical processes; that the engine-power required to overcome it varies nearly as the cube of the speed, and as a quantity called the "augmented surface," which is the quantity to be considered in fixing the dimensions of propellers; that the friction consists of two parts, one increasing and the other diminishing with the length of the vessel; that the least resistance for a given displacement and speed is given by a proportion of length to breadth which is somewhere about *seven* to *one*, and that excess of length is the best side to err on. The author states as limitations to his theory, that it does not give the entire resistance of vessels that are so bluff as to push before them or drag behind them masses of "dead water," nor of vessels so small for their speed as to raise waves that bury a considerable part of their bows; and from the latter limitation he deduces precautions to be observed in making experiments on models, in order that the results may be applicable to large ships.

Appendix to a Paper "On the Resistance of Ships." By Professor W. J. Macquorn Rankine, *F.R.S.*

This appendix contains a comparison between the sailing yachts 'Themis' (formerly 'Titania') and 'America,' founded on their published plans. The author shows, that although, from the greater size of the 'America,' and especially from the greater area and breadth of her load water-line, her capacity for carrying sail must be greater than that of the 'Themis,' the "augmented surfaces" of those two vessels are almost exactly equal; so that, according to the theory set forth in the paper, the 'America' ought to be the more speedy vessel—a result agreeing with that of the well-known trial of speed. The "augmented surface" of the 'Themis' is increased by the very hollow form of her cross-sections, so as to be greater than it might have been, if those sections had been nearly triangular, as they are in the 'America.'

On the Application of Workshop Tools to the Construction of Steam-Engines and other Machinery. By J. Robinson.

The author made some observations upon the planing machine, the slide-lathe, the screw-cutting lathe, giving any range of motion; the radial drill, the slot drill, the key grooving machine, the shaping machine, the bolt and nut cutting machine, &c. The steam-hammer, the punching machine, the riveting machine, were also dilated upon. The last-named was worked by hydraulic power, by Sir William Armstrong. The export of machinery, from 1856 to 1860, amounted to £17,000,000. No such quantity of machinery could have been made and exported, he submitted, had it not been for the important tools enumerated.

On a System of Telegraphic Communication adopted in Berlin in case of Fires. By C. W. Siemens, *F.R.S.*

By means of this arrangement, immediately after a fire occurred the police at every station in the town could be informed of the occurrence, and of the district in which the fire had occurred. He said it was found by the adoption of this system that the fire-engine was generally on the ground five minutes after the alarm had been given. He also explained and exhibited a system of railway signalling extensively adopted on the Continent, which rendered collisions almost impossible. This system of fire-alarm telegraph was first established at Berlin in 1849, by the firm of Siemens and Halske, and has since been adopted at several other continental cities, including St. Petersburg.

On Iron Construction; with Remarks on the Strength of Iron Columns and Arches. By F. W. Sheilds, *M.I.C.E.*

The author remarked, that in various constructions, such as bridges, ships, and roofs, the materials formerly used were being rapidly superseded by iron. Nor was this change confined to England and the seats of iron manufacture alone. In fact, it appeared almost anomalous that a bridge of this costly material, conveyed from England at great expense, should supersede with economy, in Australia, India, Russia, or Spain, the apparently cheaper materials found in abundance on the spot.

The explanation of this apparent anomaly is found in the greater strength of iron, size for size, than of the other materials, and in its capacity for being manufactured in such varied shapes and sizes, that just so much scantling may be given to each part of a structure as will meet the strain on that part, without any being wasted or lost to use. In a framing, an undue increase of scantling to some of its parts does not add strength to the whole structure, as its endurance is limited by the strength of its weakest part; and such increase but involves the addition of useless weight and expense, besides endangering the stability of the construction by the failure of its weaker portions.

It is therefore requisite, on the grounds not only of economy but of safety, that practical men dealing with ironwork should be versed in calculating the strains upon such framings. The author would not attempt here to give an abstract of these principles, as he had briefly stated them in a recent publication on the strains on structures of ironwork; but in the more simple cases of the resistance to pressure of columns and arches, he would state the results of his experience. After allusion to the experiments of Messrs. Fairbairn and Eaton Hodgkinson, he stated that, from large experience in the construction of the Crystal Palace at Sydenham and other works, he had adopted the following rules for the safe load borne by cast-iron columns of good construction, with flat ends and with base-plates at their bearings. For hollow columns of 20 to 24 diameters in length,—

	Columns may be loaded with
If cast $\frac{3}{4}$ inch thick or upwards....	2 tons per square inch sectional area of iron in column.
" $\frac{5}{8}$ " "	$1\frac{3}{4}$ " " "
" $\frac{1}{2}$ " "	$1\frac{1}{2}$ " " "
" $\frac{3}{8}$ " "	$1\frac{1}{4}$ " " "
For columns of 25 to 30 diameters in length,—	
" $\frac{3}{4}$ inch thick or upwards....	$1\frac{3}{4}$ " " "
" $\frac{5}{8}$ " "	$1\frac{1}{2}$ " " "
" $\frac{1}{2}$ " "	$1\frac{1}{4}$ " " "
" $\frac{3}{8}$ " "	1 " " "

the cause of the diminution in loading being that thin and light columns are more liable to weakness from inequalities of casting.

In the apportionment of iron to meet the strain or thrust of an arch, it is usual to allow about $2\frac{1}{2}$ tons of pressure to each sectional inch in cast, and 4 tons in wrought iron; also, in very flat arches, to consider the flat central portion as a girder, and to give to its top and bottom such flanges as a simple beam of its length and depth would require.

On Patent Tribunals. By W. Spence.

The author argued against the practicability of any plan of preliminary investigation of the merits of inventions before granting patents in any form that had been suggested. He, however, thought that the difficulties in the way of preliminary investigation did not apply to the trial of cases after the filing of the complete specifications, and he fully concurred in the necessity of a special tribunal for trying patent cases.

On the Deflection of Iron Girders. By B. B. Stoney, *M.R.I.A.*

The author showed, by diagrams drawn to an exaggerated scale, that the deflection of double-flanged girders is not affected by the mode of construction adopted in the web; in other words, if two girders of equal length and depth, one a lattice, the other a plate girder, have the same strains per sectional unit transmitted through their flanges, they will both deflect to the same extent. Also, when a girder is of uniform strength, that is, when all parts are equally proportioned to the transmitted strain, the deflection-curve will be a circle, and the central deflection may be simply expressed by the following equation—

$$D=\frac{l\lambda}{8d},$$

where D = the central deflection.
l = the length of the girder.
d = the depth.
λ = the difference in length of the flanges after deflection.

On Bailey's Steam-pressure Gauge. By W. Tate.

On Property in Invention and its Effects on the Arts and Manufactures. By T. Webster, *F.R.S.*

The author pointed out that considerations of public policy had led to certain rules or laws respecting the use and enjoyment of all property, and that the same principles to which the origin of all property is to be referred had peculiar claims to recognition with regard to the inventor. To say that an inventor may retain command over his invention by secrecy is to propose an impossibility in a majority of cases, and in a few cases in which it might be done the effect would be to convert his art into a mystery and to introduce practices long since condemned. The author pointed out the fallacy of stigmatizing patents as contrary to the principle of free trade, as was commonly done. He admitted the injury done by the indiscriminate grant of patents; and this, which might be remedied, ought not to be used as an argument against the system. He pointed out that although for small inventions and such as could be quickly introduced a patent might not be needed, yet that where time and capital were required to introduce the inventions into use, such inventions would not be made and perfected useless the inventors were protected from piracy by letters patent. He thought the cases of obstruction, in practice, were more imaginary than real. The law admitted of successive patents for improvements, and practically it was rare that a prior inventor would not come to reasonable terms with a subsequent one. At all events, the case might be met by applying to this species of property that which the legislature had already applied to other kinds of property, viz., the powers of the Lands Clauses Consolidation Act, where lands were taken compulsorily, and compel patentees to grant licenses upon equitable terms.

APPENDIX.

On the Causes of the Phenomena of Cyclones. By Isaac Ashe, *A.B., M.B.*

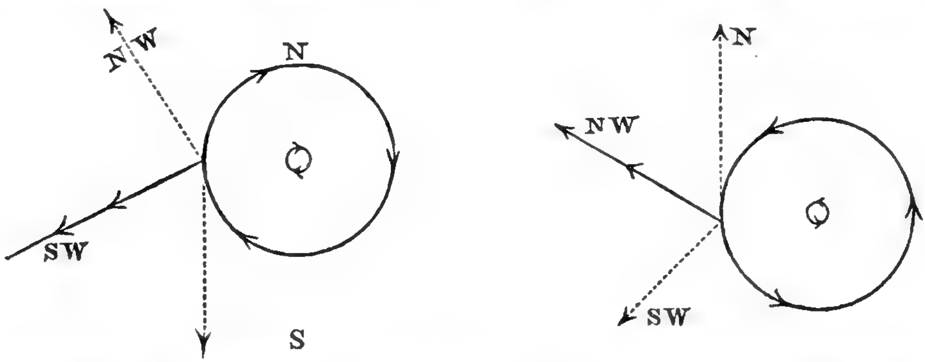
The author criticised Mr. Redfield's view of the formation of cyclones, as given in Silliman's Journal, vol. xxxiii. p. 56, namely, that they are formed by the meeting in the upper regions of the atmosphere of two currents, a hot and a cold, which, infolding each other, generate a horizontal rotation in a body of air, and that, one extremity of this rotating body of air descending to the earth, the horizontal rotation is changed to a vertical one. Such a view would not account for the fact that the rotation is invariably from left to right in the southern hemisphere, and from right to left in the northern, as the direction of the vertical rotation would be altered according as it would be one or the other extremity of the vertically rotating body of air that chanced to descend to the earth. Mr. Ashe considered that the invariably observed phenomenon pointed to a cause admitting of no variation, and suggested that, in consequence of the diurnal rotation of the earth being slower as we go polewards, a volume of air, rushing towards a centre of rarefaction near the equator, would, if it came from polewards, proceed westward of the centre of rarefaction, and if it came from the equatorial side, would proceed to eastward of it, and that the two currents thus meeting would form a mechanical "couple" of forces, and generate a rotation which, it will be easily seen, must be invariably from left to right in the southern hemisphere, and from right to left in the northern, as is the fact.

He corroborated this view by the consideration that, according to it, cyclones should not be formed near the equator, since the "couple" of forces would there become nearly opposite—a view exactly in accordance with observed facts; whereas, on Mr. Redfield's hypothesis, they ought to be oftener found there, since at the equator the surface and upper currents of the atmosphere become interchanged, and so would have a tendency to produce horizontal rotation, as assumed by him.

The author suggested that rarefaction might be produced by the latent heat evolved by a copious precipitation of aqueous vapour in any particular region, assenting to Col. Reid's view that cyclones are not caused by islands.

With regard to the continued ascent of air in a cyclone, the author criticised Mr. Redfield's views as expressed in the following extract from 'Silliman's Journal,' vol. xxxiii. p. 59, ascribed in the Index to that writer, viz.:—"The condition of force by which the propulsion is maintained is found in the pressure of the surrounding atmosphere upon all sides of the whirling and therefore mechanically rarefied column; and if the expansive whirling motion be sufficiently active to produce nearly a vacuum at the centre, the external propelling force will be nearly 15 lbs. to the square inch." The author observed that the pressure, as registered by the barometer, never exceeded about 1 lb. to the square inch; and contended that if even this pressure were to operate as a motive force at all, it would cause, not continuance of the rotation, but total collapse of the cyclone from the bottom upwards, —a conclusion which he illustrated by the disappearance of a water-spout in this manner, and also by an experiment with a bottle containing some water in a state of rapid rotation, in which a similar result was shown to follow from the pressure of the column of water as the centrifugal force declined. He considered that the external pressure of the atmosphere was the *effect,* and not the *cause,* of the continuance of the cyclone, and suggested as a *cause* of this continuance the passage of a current of air over the top of the cyclone, in the upper regions of the atmosphere, analogous to the draught similarly caused in a chimney; since Maury has shown that such a current actually exists in the upper atmosphere, blowing in a direction the reverse of the trade-wind, the rotating column of air composing the cyclone being capable of being regarded as a chimney. The author had observed that such a current, passing over the top of the funnel of a steamer, caused the smoke to rotate in two spiral columns, folding into each other below on the leeward side of the funnel; so that if a person stood facing the funnel with his back to the wind, the left-hand column would correspond, inside the funnel, with the cyclones of the southern hemisphere, and the right-hand column with those of the northern. Since such an upper current, as shown by Maury, would descend and become a surface-current at the tropics, we might expect cyclones often to die out here; and the author referred to the opinion of Lieut. Fyers, R.E., Secretary to the Meteorological Society of Mauritius, that such was sometimes the fact, as in the case of the Mauritius hurricane of November 1854, as evidenced by the log of the ship 'Sesostris' (see 'Transactions of the Meteorological Society of Mauritius,' vol. iii. p. 18). Mr. Ashe also exhibited a chart of storms traced in the South Indian Ocean by the above-mentioned Society, in which, out of twelve storms, only one was traceable as far as 29° S. lat., while ten could not be traced beyond 25° S.

The shape of a cyclone the author considered to be, not really circular, but elliptical, the major axis running from west to east, and the vortex being on the east side of the minor axis, since this figure would result from the fact that a particle of air proceeding towards the vortex from polewards would go more to the westward than a particle coming from the same distance on the side of the equator would go to eastwards of the vortex, owing to the increasing ratio with which the circumferences diminish in the circles formed by the parallels of latitudes as the distance of these from the equator increases; for the radii of these circles are equal to the cosines of angles increasing in arithmetical progression from 0° to 90°. Hence Mr. Ashe deduced that the westernmost portion of the cyclone would be the most slowly rotating, considering the cyclone merely with reference to its own internal motion of rotation, and not with reference to the difference which would be perceived by a ship at sea, the latter being due to the fact that one side of a cyclone moved with the trade-wind, and the opposite against it, and resulting in a general translation of the entire cyclone, along with the trade-wind, to be considered separately; but the most westerly quarter of the cyclone being the slowest moving as regards its own internal rotation, it follows that the cyclone will progress along a line at a tangent to this, that is to say, southwards or nearly so in the southern hemisphere, and northwards or nearly so in the northern hemisphere, the direction of rotation being here the reverse of what it is in the southern hemisphere. Combining this, the proper motion of the cyclone, with the motion derived from the trade-wind, both being represented by the dotted lines in the annexed figure of a cyclone in the southern hemisphere, we obtain the actual motion in a direction S.W.



or thereabouts, as indicated by the continuous line in the figure,—a result corresponding exactly with what is observed to be in fact the case. Similarly in the northern hemisphere, combining the proper motion of the cyclone, which on this theory would be about north, with the S.W. motion derived from the trade-wind, we should have the actual motion of the cyclone in a north-west direction, which again corresponds exactly with the fact as observed within the tropics. Since the causes above inferred to produce the proper motion of the cyclone would act less powerfully near the equator, it follows, on this theory, that the actual motion of the cyclone would be slower there than at subsequent portions of its course, which is constantly observed to be the case; and a chart of a remarkable storm, which occurred near Mauritius in January 1855, was laid before the Section by the author (see vol. iii. p. 23, 'Transactions of the Meteorological Society of Mauritius'), in which this was manifested in a striking degree, in consequence, as supposed by Mr. Ashe, of the influence of the trade-wind being at a minimum at that season—a view supported by the direction in which the storm travelled, which was S.S.E., corresponding very nearly with the proper motion of cyclones in the southern hemisphere, as deduced above.

In all cases in which the influence of the trade-wind is *nil*, whether owing to the season or the latitude, we would expect that a cyclone proceeding rapidly polewards would derive considerable easting from the circumstance of its having left lower latitudes where the diurnal rotation is more rapid than in the places it is arriving at.

Mr. Ashe regarded the recurving so constantly observed in cyclones in the South Indian Ocean as being due to this circumstance, and exhibited a chart containing the observed tracks of several cyclones (see chart i. vol. iii. of 'Transactions of the Meteorological Society of Mauritius'), to show on the one hand that the recurving is not owing to the presence of the island of Mauritius, as commonly supposed, since several of the cyclones recurved in open sea far from land, and, on the other hand, that the recurving was to be connected with the latitude,—as it occurred, as shown in the chart, just where the component of motion due to the trade-wind was vanishing, and the cyclone was assuming its own proper motion in a southerly direction, with easting derived from the cause above mentioned.

In the case of cyclones in the North Atlantic, the author referred the recurving observed about the peninsula of Florida to the same causes, it being in about the same latitude north, aided, no doubt, by the continent of North America, which, extending for thousands of miles, is very different from the small island of Mauritius, only 30 miles across, and along the coast-edge of which the cyclone rolls like a wheel along a plane surface. The slight westward trending of the direction of the trade-wind, as we go further from the equator, would undoubtedly tend to produce a slight southerly deflection of the cyclone from an early part of its course, which deflection would be aided by the increase of speed in the proper motion of the cyclone due to the causes above mentioned; and such deflection is exhibited in the charts produced by the author.

In accordance with this theory also we would expect that, as the force of the trade-wind must increase from the summer to the winter solstice, we should have a northerly trending of the track of cyclones during that period, due to this increase of force in this component of their motion; and, to show that facts were in accordance with this theory, Mr. Ashe quoted the following passage from a paper read by Lieut. Fyers, R.E., reported in the 'Transactions of the Meteorological Society of Mauritius,' 1855, p. 58, viz.:—"As far as my experience goes, the November and December storms invariably take a *southern* course to the eastward of Rodriguez, and, as the season advances, in January, February, and March, they take a more westerly direction, sometimes passing north of Mauritius and continuing to the coast of Madagascar, at others passing between Rodriguez and Mauritius,"—a statement which, on referring to the map, and recollecting that the writer took his point of view from Mauritius, we find exactly to correspond with a northerly trending of the track of cyclones during those months.

The increase in diameter, and decrease in violence of a cyclone, as it progresses, Mr. Ashe attributed to the engagement of more air in the rotatory motion, owing to the friction exercised by the walls, as it were, of the cyclone against the surrounding atmosphere, while, as the force did not increase in consequence, the velocity of the mass moved would necessarily diminish.

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CONTENTS:—Rev. P. Kelland, on the Present state of our Theoretical and Experimental Knowledge of the Laws of Conduction of Heat;—G. L. Roupell, M. D., Report on Poisons;—T. G. Bunt, Report on Discussions of Bristol Tides, under the direction of the Rev. W. Whewell;—D. Ross, Report on the Discussions of Leith Tide Observations, under the direction of the Rev. W. Whewell;—W. S. Harris, upon the working of Whewell's Anemometer at Plymouth during the past year;—Report of a Committee appointed for the purpose of superintending the scientific co-operation of the British Association in the System of Simultaneous Observations in Terrestrial Magnetism and Meteorology;—Reports of Committees appointed to provide Meteorological Instruments for the use of M. Agassiz and Mr. M'Cord;—Report of a Committee to superintend the reduction of Meteorological Observations;—Report of a Committee for revising the Nomenclature of the Stars;—Report of a Committee for obtaining Instruments and Registers to record Shocks and Earthquakes in Scotland and Ireland;—Report of a Committee on the Preservation of Vegetative Powers in Seeds;—Dr. Hodgkin, on Inquiries into the Races of Man;—Report of the Committee appointed to report how far the Desiderata in our knowledge of the Condition of the Upper Strata of the Atmosphere may be supplied by means of Ascents in Balloons or otherwise, to ascertain the probable expense of such Experiments, and to draw up Directions for Observers in such circumstances;—R. Owen, Report on British Fossil Reptiles;—Reports on the Determination of the Mean Value of Railway Constants;—D. Lardner, LL.D., Second and concluding Report on the Determination of the Mean Value of Railway Constants;—E. Woods, Report on Railway Constants;—Report of a Committee on the Construction of a Constant Indicator for Steam-Engines.

Together with the Transactions of the Sections, Prof. Whewell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWELFTH MEETING, at Manchester, 1842, *Published at* 10*s.* 6*d.*

CONTENTS:—Report of the Committee appointed to conduct the co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—J. Richardson, M.D., Report on the present State of the Ichthyology of New Zealand;—W. S. Harris, Report on the Progress of Meteorological Observations at Plymouth;—Second Report of a Committee appointed to make Experiments on the Growth and Vitality of Seeds;—C. Vignoles, Report of the Committee on Railway Sections;—Report of the Committee for the Preservation of Animal and Vegetable Substances;—Lyon Playfair, M.D., Abstract of Prof. Liebig's Report on Organic Chemistry applied to Physiology and Pathology;—R. Owen, Report on the British Fossil Mammalia, Part I.;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—L. Agassiz, Report on the Fossil Fishes of the Devonian System or Old Red Sandstone;—W. Fairbairn, Appendix to a Report on the Strength and other Properties of Cast Iron obtained from the Hot and Cold Blast;—D. Milne, Report of the Committee for Registering Shocks of Earthquakes in Great Britain;—Report of a Committee on the construction of a Constant Indicator for Steam-Engines, and for the determination of the Velocity of the Piston of the Self-acting Engine at different periods of the Stroke;—J. S. Russell, Report of a Committee on the Form of Ships;—Report of a Committee appointed "to consider of the Rules by which the Nomenclature of Zoology may be established on a uniform and permanent basis;"—Report of a Committee on the Vital Statistics of large Towns in Scotland;—Provisional Reports, and Notices of Progress in special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Lord Francis Egerton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTEENTH MEETING, at Cork, 1843, *Published at* 12*s.*

CONTENTS:—Robert Mallet, Third Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at Various Temperatures, upon Cast Iron, Wrought Iron, and Steel;—Report of the Committee appointed to conduct the co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Sir J. F. W. Herschel, Bart., Report of the Committee appointed for the Reduction of Meteorological Observations;—Report of the Committee appointed for Experiments on Steam-Engines;—Report of the Committee appointed to continue their Experiments on the Vitality of Seeds;—J. S. Russell, Report of a Series of Observations on the Tides of the Frith of Forth and the East Coast of Scotland;—J. S. Russell, Notice of a Report of the Committee on the Form of Ships;—J. Blake, Report on the Physiological Action of Medicines;—Report of the Committee on Zoological Nomenclature;—Report of the Committee for Registering the Shocks of Earthquakes, and making such Meteorological Observations as may appear to them desirable;—Report of the Committee for conducting Experiments with Captive Balloons;—Prof. Wheatstone, Appendix to the Report;—Report of the Committee for the Translation and Publication of Foreign Scientific Memoirs;—C. W. Peach on the Habits of the Marine Testacea;—E. Forbes, Report on the Mollusca and Radiata of the Ægean Sea, and on their distribution, considered as bearing on Geology;—L. Agassiz, Synoptical Table of British Fossil Fishes, arranged in the order of the Geological Formations;—R. Owen, Report on the British Fossil Mammalia, Part II.;—E. W. Binney, Report on the excavation made at the junction of the Lower New Red Sandstone with the Coal Measures at Collyhurst;—W.

Thompson, Report on the Fauna of Ireland: Div. *Invertebrata*;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Earl of Rosse's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FOURTEENTH MEETING, at York, 1844, *Published at* £1.

CONTENTS:—W. B. Carpenter, on the Microscopic Structure of Shells;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Œconomy of the *Araneidea*, made in Great Britain;—Earl of Rosse, on the Construction of large Reflecting Telescopes;—Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory;—Report of the Committee for Registering Earthquake Shocks in Scotland;—Report of a Committee for Experiments on Steam-Engines;—Report of the Committee to investigate the Varieties of the Human Race;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds;—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—Sixth Report of the Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Prof. Forchhammer on the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate;—H. E. Strickland, Report on the recent Progress and Present State of Ornithology;—T. Oldham, Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland;—Prof. Owen, Report on the Extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that continent of large Marsupial Representatives of the Order Pachydermata;—W. S. Harris, Report on the working of Whewell and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843;—W. R. Birt, Report on Atmospheric Waves;—L. Agassiz, Rapport sur les Poissons Fossiles de l'Argile de Londres, with translation;—J. S. Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTEENTH MEETING, at Cambridge, 1845, *Published at* 12*s*.

CONTENTS:—Seventh Report of a Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lt.-Col. Sabine, on some points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843;—R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-Registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phænomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at* 15*s*.

CONTENTS:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical

Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—J. Percy, M.D., Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18*s.*

CONTENTS:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water;—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phænomena;—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 Phænomena of Plants and

Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds; —F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at* 15s.

CONTENTS:—R. Mallet, First Report on the Facts of Earthquake Phænomena;—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 Phænomena 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* 16s. 6d.

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 Œconomical 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 Phænomena;—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* 15s.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phænomena;—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 Œconomy 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 Œconomy 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 Phænomena (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 Phænomena (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 Phænomena: 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 $\Sigma_0^{t} \frac{{}^{-\alpha}\alpha^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$, α étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinasion 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 Hargrave, 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' 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 Steam-ship 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.

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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 Steam-ship Performance;—Interim Report on the Gauging of Water by Triangular Notches;—List of the British Marine Invertebrate Fauna.

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