REPORT

OF THE

TWENTY-EIGHTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT LEEDS IN SEPTEMBER 1858.

LONDON:
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ALERE

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Page 85, line 21, *for* south, *read* north.
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LIST OF PLATES.

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 Robison, 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 T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, 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.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S.

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 31, 1850.	Right Hon. the Lord Provost of Edinburgh. The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S.L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal. IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich. Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society. BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, M.R.I.A., Pres. R.S. Sir Henry T. DelaBeche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast. Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., & Pres. Camb. Phil. Society. HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Philos. Society. William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S.L. & E., F.R.A.S. Joseph Brooks Yates, Esq., 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. Prof. Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, M.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 LordMayor 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. Prof. 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.	Prof. J. Nicol, F.R.S.E., F.G.S. Prof. Fuller, M.A. John F. White, Esq.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE GENERAL TREASURER'S ACCOUNT from 26th August 1857 (commencement of DUBLIN MEETING) to 22nd September 1858 (at LEEDS).

PAYMENTS.

		£	s.	d.
By paid Expenses of Dublin Meeting, Sundry Printing, Binding, Advertising, and Incidental Payments by the General Treasurer and Local Treasurers		376	5	7
Printing Report of the Twenty-sixth Meeting, Engraving, &c.		657	3	9
Salaries, 12 months		350	0	0
Purchase of £1200 3 per cent. Consols		1048	10	0
Maintaining the Establishment of Kew Observatory		500	0	0
Earthquake Waves' Experiments		25	0	0
Dredging on the West Coast of Scotland		10	0	0
Dredging near Dublin		5	0	0
Vitality of Seeds' Experiments		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
Vegetable Imports of Scotland		10	0	0
Balance at the Bankers	214 4 3			
Ditto due from the General Treasurer and Local Treasurers	24 9 0			
		238	13	3
		£3289	10	9

RECEIPTS.

		£	s.	d.
To Balance brought on from last Account		123	17	10
Composition for future Publications		5	0	0
Life Compositions at Dublin and since		180	0	0
Annual Subscriptions, ditto ditto		489	0	0
Associates' Tickets, ditto		900	0	0
Ladies' Tickets, ditto		569	0	0
12 Months' Dividends on £6200 3 per cent. Consols		181	7	0
Sale of £700 3 per cent. Consols		662	17	0
From Sale of Publications—	£. s. d.			
viz. For Reports of Meetings	111 13 8			
Catalogues of Stars, Dove's Lines	66 15 3			
		178	8	11
		£3289	10	9

Examined and found correct.

ROBERT HUTTON, NORTON SHAW, JAMES YATES, *Auditors.*

II. Table showing the Names of Members of the British Association who have served on the Council in former years.

Acland, Sir Thomas D., Bart., F.R.S.
Acland, Professor H. W., M.D., F.R.S.
Adams, J. Couch, M.A., F.R.S.
Adamson, John, Esq., F.L.S.
Ainslie, Rev. Gilbert, D.D., Master of Pembroke Hall, Cambridge.
Airy, G. B., D.C.L., F.R.S., Astronomer Royal.
Alison, Professor W. P., M.D., F.R.S.E.
Allen, W. J. C., Esq.
Anderson, Prof. Thomas, M.D.
Ansted, Professor D. T., M.A., F.R.S.
Argyll, George Douglas, Duke of, F.R.S.
Arnott, Neil, M.D., F.R.S.
Ashburton, William Bingham, Lord, D.C.L.
Atkinson, Rt. Hon. R., Lord Mayor of Dublin.
Babbage, Charles, Esq., M.A., F.R.S.
Babington, C. C., Esq., M.A., F.R.S.
Baily, Francis, Esq., F.R.S. (deceased).
Baker, Thomas Barwick Lloyd, Esq.
Balfour, Professor John H., M.D., F.R.S.

Barker, George, Esq., F.R.S. (deceased).
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M. l'Abbé Moigno, *Paris.*
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Dr. N. Nordenscìold, *Finland.*
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Gustave Plaar, *Strasburg.*
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Professor Plücker, *Bonn.*
M. Constant Prévost, *Paris.*
M. Quetelet, *Brussels.*
Prof. Retzius, *Stockholm.*
Professor C. Ritter, *Berlin.*
Professor H. D. Rogers, *Boston, U.S.*
Professor W. B. Rogers, *Boston, U.S.*
Professor H. Rose, *Berlin.*
Herman Schlagintweit, *Berlin.*
Robert Schlagintweit, *Berlin.*
Dr. Siljestrom, *Stockholm.*
M. Struvè, *Pulkowa.*
Dr. Svanberg, *Stockholm.*
M. Pierre Tchihatchef.
Dr. Van der Hoeven, *Leyden.*
Baron Sartorius von Waltershausen, *Göttingen.*
Professor Wartmann, *Geneva.*

Report of the Council of the British Association as presented to the General Committee at Leeds, September 22nd, 1858.

1. With reference to the subjects referred to the Council by the General Committee at Dublin, the Council have to report as follows:—

a. The General Committee passed the following resolution, viz.:—

"That it is of great importance to the progress of Science that the Magnetic Observations which have already added so much to our knowledge of terrestrial magnetism, should be continued. That the influence of the Association will be well employed in attaining this object, and that it is desirable to obtain the cooperation of the Royal Society. That a Committee be appointed, consisting of the President, the Rev. Dr. Robinson, and Major-General Sabine, to request, on the part of the British Association, the cooperation of the President and Council of the Royal Society, and to take in conjunction with them such steps as may appear necessary, including, if it be thought desirable, an application to Government."

A copy of this resolution was transmitted soon after the Dublin Meeting by the President, Dr. Lloyd, to Lord Wrottesley, President of the Royal Society, accompanied by the following letter:—

"Nov. 6, 1857.

"My Lord,—At the Meeting of the British Association which was held at Dublin in August last, a Resolution was adopted proposing the continuance of the system of Magnetical Observations which was commenced under the auspices of the Royal Society and of the British Association in 1840; and a Committee, consisting of the President of the Association, Rev. Dr. Robinson, and General Sabine, was appointed, to request the cooperation of the President and Council of the Royal Society in the endeavour to attain this object, and to take in conjunction with them such steps as may appear desirable for that end. If this proposal should commend itself to your Lordship's judgment, and that of the Council of the Royal Society, I have to request, on the part of the gentlemen above named, that you will be pleased to nominate a Committee of the Royal Society to confer with them, and to take such further steps in conjunction with them as may seem expedient.

"I have the honour to be, My Lord,
"Your most obedient Servant,
(Signed) "H. Lloyd."

"*To the Right Hon. the Lord Wrottesley, P.R.S.*"

In consequence of this letter, the President and Council of the Royal Society appointed a Committee, consisting of Sir John Herschel, Bart., the Rev. Dr. Whewell, the Rev. The Dean of Ely, and the Astronomer Royal (who had been members of the Committee of Physics, by whom the former Report on terrestrial magnetism in 1839-40 had been drawn up) to consider the progress and present state of Magnetical Investigation; and to take, in conjunction with the Committee appointed by the British Association, such steps as should appear advisable for its further prosecution; including, if it should be deemed desirable, an application to Government.

The mode of proceeding pursued by the two Committees has been hitherto that of independent deliberation, with occasional intercommunication by correspondence. The conclusions which have been arrived at by the two Committes being, it is understood, substantially the same, a united Meeting has been appointed to take place at Leeds, in the present week, at which a joint report may be drawn up, and may be presented to the General Committee at its meeting on Monday next, when such further steps may be taken in reference to the subject as may appear desirable.

b. The General Committee assembled at Dublin directed that "an application should be made to Her Majesty's Government to send a vessel to examine and survey the entrance to the Zambesi River in South Africa, and to ascend the river as far as may be found practicable for navigation."

The President, and the Committee to whom the charge of this application was entrusted, having placed themselves in communication with Dr. Livingstone, presented the following Memorial to the Earl of Clarendon, Her Majesty's Secretary of State for Foreign Affairs:—

"Dr. Livingstone's successful travels in Africa, and the account which he has given of them at public meetings in the metropolis and in several of the principal provincial towns of the United Kingdom, have excited throughout the country a strong desire to obtain more full particulars regarding the productions, capabilities, and accessibility of that portion of the globe.

"The Zambesi River appears by Dr. Livingstone's account to furnish means of communication with the interior of Southern Africa similar to those which the Quorra and Binue have been found to afford in Central Africa. The object of the present application is to bring under the consideration of Her Majesty's Government the expediency of availing themselves of the opportunity of Dr. Livingstone's return to Africa, to employ a suitable vessel in the ensuing season to obtain, with his assistance, a more correct knowledge than we now possess, of the facilities which the Zambesi would afford for commerce, and of the extent to which its waters may be navigable; and also to procure a more exact knowledge of the natural productions of the country, and of the availability of the supplies of coal and other mineral substances which are stated to exist in the vicinity of the river."

Early in November the Committee, accompanied by Dr. Livingstone, were favoured with a personal interview by Lord Clarendon, who was pleased to express a warm interest in the proposed Expedition, and promised that it should receive the favourable consideration of Her Majesty's Government. The expectation thus raised has been fully realized; a vote of money was moved by the Chancellor of the Exchequer, and sanctioned by the House of Commons; and the Expedition has since sailed, having had the advantage of receiving from the Royal Society, on Lord Clarendon's invitation, suggestions as to the scientific objects which the Expedition may be made to subserve, without interference with its primary and immediate purpose, and having been furnished at the Observatory of the British Association at Kew, with scientific instruments, and with personal instruction in their use.

c. The General Committee, at Dublin, directed that application should be made to Her Majesty's Government "to send a vessel to the vicinity of the Mackenzie River, for the purpose of making a series of Magnetic Observations with special reference to the determination of the laws now known to rule the magnetic storms." The General Committee entrusted this application to the President, assisted by a Committee named in the Resolution. A Memorial, setting forth the grounds and object of the application, having been prepared by the Committee, was presented to Lord Palmerston on the 31st of October, with a request from the Committee to be favoured with an interview.

The Memorial was as follows:—

"Among the most important results of scientific research during the last twenty years, is the addition which has been made to our knowledge of Terrestrial Magnetism. The variation of its direction and intensity dependent on the observer's position on the globe, have been ascertained with a precision which already affords material assistance to the seaman; and those variations which are connected with the hour of the day, or season of the year, have been also carefully investigated. But, as always happens in real progress, the advance which has been made has shown new ground which ought to be explored. Without referring to the magnetic influence, which we have now reason to believe is exerted on our planet both by the sun and moon, a still more interesting fact has recently been established. It has long been known that the earth's magnetism is affected by sudden disturbances, occasionally so great as even to interfere with its practical applications; but it has been very recently discovered that these magnetic storms (as they have been called) are themselves subject to periodic laws. Their study is evidently of the highest importance towards the discovery of the physical causes which are engaged in producing magnetic phenomena, and a fortunate circumstance has pointed out one method of pursuing it. During the years in which Her Majesty's Ship 'Plover' was stationed at Point Barrow, as a part of the squadron which was searching for the traces of Sir J. Franklin, and his noble companions, her officers, under the superintendence of their gifted commander R. Maguire, made a valuable series of magnetic observations, the more precious from their peculiar position, and the great care with which they were conducted. On reducing these and comparing their results with those obtained at Toronto, the most famous of the British Magnetic Observatories, some very remarkable facts were elicited respecting the magnetic storms. At both stations they occur simnltaneously; but with the significant difference that their directions are opposite. This indicates so clearly the relation of these disturbances to a point somewhere between Point Barrow and Toronto, that it appeared to the Physical Section of the British Association, when discussing at its late Meeting these observations, of high importance to have them continued and extended. For this purpose a location in or near Mackenzie River appears the most suitable, as very well situated with respect to the other two, and as easily accessible without any extraordinary risk, or chance of long detention. The same instruments are available; and as there are many officers in Her Majesty's Navy perfectly competent to use them, it is confidently expected that the result would be alike beneficial to this department of Physical Science, and honourable to our country."

No reply having been received to this communication, the following letter was addressed, on the 4th of January, by the President, to G. C. Barrington, Esq., private Secretary to Lord Palmerston:—

"January 4, 1858.

"Sir,—On the 31st of October I communicated to Lord Palmerston a resolution adopted by the British Association for the Advancement of Science, making application to Her Majesty's Government to send a vessel to the vicinity of the Mackenzie River, for the purpose of obtaining in that region certain observations, which recent discoveries in Terrestrial Magnetism had proved to be of high importance to science; and I enclosed at the same time a Memorial, setting forth in detail the grounds of the application.

"As the time for making the necessary preparations for such an expedition has now fully arrived, I trust I shall not be deemed unreasonable in recalling, through you, his Lordship's consideration to the subject.

"In reference to this part of the question, I beg to enclose a letter from Captain Maguire, who commanded H.M.S. 'Plover' in the same seas in 1852, 1853, 1854, and who is probably the best authority on the subject. It will be seen from it, that there is still sufficient time to equip a vessel for the forthcoming season. As respects the kind of vessel required, and the nature of the equipment, the same officer writes as follows, in a letter dated the 5th of November last, addressed to General Sabine:—

"'One of the despatch gun-vessels will answer very well. There are also many sailing-sloops now lying idle—such as the 'Frolic' and 'Espiègle,' or many others, that might be made available at a trifling expense. The strengthening need not be much; and a very small auxiliary steam-power, sufficient to propel the vessel two or three knots in a calm, would suffice to carry her through the land-water of the north coast from Point Barrow. The shores from thence to the Mackenzie afford, in every part, an ample supply of driftwood fit for steaming purposes.'

"As I believe that one of the chief objections, on the part of Her Majesty's Government, to further expeditions to the Arctic Seas, is the danger to the lives of the seamen employed in the service, I think it right to add, that an expedition to *this locality* will be attended with *no unusual risk*,—and that, on the other hand, it *may* afford important support to the gallant crew who are now engaged in the final search for the traces of the Franklin Expedition, if the commander should be induced by circumstances, which are not improbable, to push his vessel westward.

"I have the honour to be, Sir,

"Your obedient Servant,

(Signed) "H. Lloyd."

"*To G. C. Barrington, Esq.*"

To this letter the following reply was received:—

"Downing Street, Jan. 22, 1858.

"Sir,—In reply to your letter of the 4th instant, I am desired by Lord Palmerston to acquaint you that Her Majesty's Government do not think it advisable to take the steps recommended by you.

"I am, Sir,

"Your obedient Servant,

(Signed) "Gerald Ponsonby."

"*Rev. Dr. Lloyd.*"

2. The General Committee at Dublin having placed £500 at the disposal of the Council, to be employed in maintaining the establishment, and providing for the continuance of special researches at the Kew Observatory, the Report of the Committee to whom the Council have confided the superintendence of the Kew Observatory is herewith annexed, testifying to the great and still increasing public utility of that establishment. The General Committee will recognize with pleasure, in the contribution of £150 received from the Royal Society, for the purchase of improved tools for the workshop of the Observatory, a fresh evidence of the readiness of the President and Council of that body to aid the objects of the Kew Observatory, by special grants from time to time for particular purposes.

3. Since the communication made by the President and Council of the Royal Society to the General Committee in Dublin, relative to the formation of a "Catalogue of the Philosophical papers contained in the various scientific Transactions and Journals of all Countries" (printed copies of which communication were distributed amongst the members of the General Committee in Dublin), this important work has been commenced under the auspices and at the expense of the Royal Society. It is purposed that it should include the titles (in the original languages) of all Memoirs published in such works, in the Mathematical, Physical, and Natural Sciences, from the foundation of the Royal Society to the present time: the titles to be so arranged as to form ultimately three catalogues,—one chronological, or in the order of the memoirs in the several series,—one alphabetical, according to authors' names,—and, lastly, a third, classified according to subjects. The superintendence of this work has been undertaken by the officers of the Royal Society, assisted by a Select Committee of the Fellows.

4. The Council have added to the list of Corresponding Members of the Association the names of the following foreign gentlemen, who were present at the Dublin Meeting, and made communications to the Sections, viz.:—

Dr. Barth.
Professor Bolzani, *Kazan.*
Antoine d'Abbadie, *Paris.*
Professor Loomis, *New York.*
Viscenza Pisani, *Florence.*
Gustave Plaar, *Strasburg.*
Herman Schlagintweit, *Berlin.*
Robert Schlagintweit, *Berlin.*

5. The General Secretary has informed the Council that he communicated to His Royal Highness The Prince Consort the resolution of the General Committee at Dublin, viz.:—

"That application be made to His Royal Highness The Prince Consort for permission to elect him President of the British Association for the year 1859," and that he had received in reply the following letter:—

"Balmoral, Sept. 17, 1857.

"Sir,—I have communicated to His Royal Highness The Prince Consort your letter of the 13th inst., expressing, on the part of the Committee of the British Association, the wish that His Royal Highness would allow himself to be nominated as President of the Meeting which it is proposed to hold at Aberdeen in 1859.

"His Royal Highness cannot but feel gratified at the wish thus expressed by the Committee, though he is sensible that his own proficiency in scientific subjects is scarcely such as to entitle him to such a distinction. If, therefore, he expresses his readiness to comply with the wishes of the Committee, he begs that it may be considered merely as an expression of the deep interest which he takes in the advancement of science in this country, and as a mark of the high sense which he entertains of the importance and usefulness of the Association.

"His acceptance of the Presidency must also be considered, to a certain degree, conditional—depending upon his being in Scotland at the time proposed for the Meeting.

"His Royal Highness's time is not his own, and it is impossible for him, at this distance of time, to say whether the call of other duties may not be such as to prevent his attendance.

"I have the honour to be, Sir,
"Your most obedient Servant,
"C. GREY."

"*To Major-General Sabine.*"

6. The Report of the Parliamentary Committee of the British Association for the Advancement of Science has been received by the Council, and is herewith presented.

Report of the Kew Committee of the British Association for the Advancement of Science, for 1857-58.

Since the last Meeting of the Association, a set of Magnetical Instruments have been prepared, at the request of the Council of the Royal Society, and the constants determined for the Expedition of Dr. Livingstone to South Africa. Capt. Bedingfield, R.N. and Messrs. Livingstone and Baines, who accompany Dr. Livingstone in this Expedition, received instructions at the Observatory in the use of the instruments.

At the request of Capt. Washington, R.N., Hydrographer of the Admiralty, similar instruments were prepared for the Oregon Boundary Commission, and instructions in their use were given at the Observatory to Capt. Haig, R.A., and Lieut. Darrah, R.E.

Detailed written instructious for both Expeditions, supplementary to those contained in the Admiralty Manual, were furnished by Mr. Welsh. Such instructions necessarily occupied the time and attention of Mr. Welsh and his assistants; but as, in the opinion of the Committee, instructions for the correctly manipulating with instruments with which gentlemen appointed to a particular service are not often previously acquainted, is an essential feature in the practical working of a physical observatory, the Committee have considered it desirable that such assistance should be afforded; and it will be in the recollection of the Council that, in their last Report, the Committee stated that several gentlemen, some of whom were connected with foreign Governments, had received similar instruction.

An application having been received from M. Secchi of the Collegio Romano, on the part of the Roman Government, for Magnetical Instruments, these instruments have been prepared at the Observatory and forwarded to Rome. They consist of an Observatory Bifilar Magnetometer and Balance

Magnetometer, similar to those employed in the British Colonial Observatories, a Unifilar Magnetometer, and a Dip Circle.

Application has also been received from the Rev. Alfred Weld for Magnetical and Electrical apparatus for the Stonyhurst College; these are in course of preparation, and Mr. Weld has received instructions in the use of the magnetical instruments.

Two Dip Circles by Barrow, furnished with Dr. Lloyd's apparatus for the total force, which were sent to the Observatory preparatory to their being forwarded to the Austrian and Russian Governments, were carefully examined and adjusted.

An extensive series of observations made with various dipping-needles and circles, have confirmed the results previously obtained at the Observatory as to the value of the Magnetic dip.

The Self-recording Magnetometers have been in regular action since the 1st of January, and have performed satisfactorily; some difficulty arose in the manipulation of the Balance-magnet, but this has been surmounted, and this instrument now performs with as much accuracy and delicacy in its action as either the Declinometer or Bifilar Magnet.

The Photoheliograph erected in the dome of the Observatory was fully described in the last Annual Report; it has been repeatedly at work since the beginning of last March, and excellent photographic pictures of the solar spots and faculæ were obtained. Certain alterations have been made by Mr. Welsh in order to regulate the time of exposure of the collodion plate to the sun's action; with these alterations the instrument gives very good results, but certain improvements in the arrangements of the secondary magnifying lens are under consideration, with the view of avoiding the depiction on the collodion negative of the inequalities in the glasses which compose it.

The Committee recommend that arrangements should be made for the appointment of a competent Assistant, who will undertake the taking of the photographs and the preparing of a certain number of copies for distribution to some of the principal British and Foreign observatories.

George Whipple has been engaged to assist in the general work of the Observatory at a weekly pay of ten shillings.

Mr. Beckley's arrangement of the Anemometer described at the Cheltenham Meeting of the Association has been adopted and carried out in an apparatus made by Mr. Adie for the East India Company. This anemometer having been mounted at the Observatory, remained for some time, and was found to perform satisfactorily; it was shown to many persons, and examined by Admiral FitzRoy, General Sabine, and Mr. Osler, members of the Anemometer Committee. Certain modifications since suggested by Mr. Beckley, have been adopted in two instruments constructed by Mr. Adie for Admiral FitzRoy's department in the Board of Trade.

The verification of Meteorological Instruments has been continued on the same plan as in previous years. The following have been verified since the last meeting of the Association to the 1st of July:—

	Barometers.	Thermometers.	Hydrometers.
For the Admiralty	75		
For the Board of Trade	60	126	
For Opticians and others	86	142	150
Total	221	268	150

Among the latter are included 50 barometers and 150 hydrometers for the United States, and 6 barometers and 6 thermometers for the Portuguese Government.

Mr. Welsh is at present completing the Magnetic Survey of Scotland, for the expense of which £200 has been received by the Committee from the Admiralty.

The Committee finding it desirable that the workshop of the Observatory should be furnished with a superior lathe and planing machine, authorized their Chairman to apply to the Council of the Royal Society for the sum of £150; this amount was immediately awarded from the Donation Fund, and a very superior lathe, by Whitworth, and a planing machine have been purchased at a cost of £149 7*s*.

The present as well as the former Annual Reports of the Committee, show the practical scientific objects for which the Observatory has for so many years been used, and at no former period was it in so effective a state as at present; the valuable tools that have (by the liberality of the Royal Society) been placed in the workshop, enable Mr. Beckley to repair and make apparatus and instruments of the most complex and delicate construction; much of this work would otherwise have been sent to different workshops in the Metropolis, entailing not only great loss of time, but often a want of accuracy in the construction: the value of such arrangements in the Observatory can be easily appreciated by scientific observers.

On the 24th of last April, the Committee presented an estimate of the expenditure for the present year, a copy of which had been previously forwarded by the Chairman to the President, whose reply, addressed to General Sabine, the Committee now present as a part of their Annual Report.

"Trinity College, Dublin, December 7, 1857.

"DEAR SABINE,—I have received from Mr. Gassiot the Financial Report of the Kew Committee, which I hope may soon be laid before the Council. It appears from it that the expenditure of the Observatory is likely to increase with the increased activity of the establishment, while part of the income—that, namely, derived from the verification of meteorological instruments—will probably diminish in future years.

"I am not sufficiently acquainted with the working of the Observatory to say, from my own knowledge, how far an augmentation of the existing staff is necessary. But if the Council should judge that it is—as stated in the Report of the Committee—they will have to consider from what *external* source provision may be made for the increased expenditure; for I presume that it will not be thought prudent, that the Association, with its fluctuating and uncertain income, should augment its grant beyond the present amount.

"Upon this point I may remark, that the President and Council of the Royal Society have already evinced their sense of the value of the Observatory, by making a liberal grant to it for a *special* object; and that it is therefore not improbable that they may be willing to contribute *permanently* to its support. Its objects are at least as clearly allied to those of the Royal Society, as to those of the British Association; and if it should be deemed that those objects have been in great measure attained, and that the establishment has proved itself deserving of permanent maintenance, it would seem expedient to place it on a more fixed basis than the present.

"I will only add, that believing, as I do, that the Observatory has already done much, and is capable of doing more, for the advancement of physical science, I should deplore the restriction of its efficiency, by insufficient pecuniary means, as a *loss to science*.

"Believe me, sincerely yours,

"H. LLOYD."

"*To General Sabine, R.A., &c.*"

The following is a Statement showing the expense of the last two years; an additional Assistant is now indispensable as a Photographer; and as the work of the Observatory increases, and its capabilities for the purposes of science become further developed, the probable future expenditure cannot be fairly estimated at less than £800 per annum.

STATEMENT.

	1857. £	s.	d.		1858. £	s.	d.
Salaries	397	5	0	....	471	8	0
Apparatus:—							
Materials, Tools, &c.	28	10	7	....	59	6	4
Ironmonger, &c.	66	9	4	....	19	13	5
Stationery, &c.	24	9	8	....	20	11	0
Coals and Gas	19	0	2	....	47	10	8
House Expenses	17	10	4	....	20	11	8
Porterage and Petty Expenses	5	19	3	....	6	12	4
Rent of Land	21	0	0	....	21	0	0
	£580	4	4	....	676	13	5

The above is the actual expenditure, but the real annual increase in salaries is about £61: the difference in the above statement arises from the termination of the financial year being one month later than last year. In the detailed statement of receipts and expenditure, it will be observed that the amount received for verification of meteorological instruments has decreased, arising from the circumstance that the Meteorological department of the Government is now well provided with a store of instruments for its use.

As the financial position of the Observatory will probably be brought forward by the Council at the General Meeting of the Association at Leeds, the Committee suggest that the time has now arrived when strenuous efforts should be made to obtain such an amount of pecuniary aid as would ensure the permanent efficient working of this practical physical Observatory; for although the establishment is conducted with the strictest economy, the necessary work connected with the Observatory unavoidably creates a corresponding increase in the amount of the annual expenditure.

JOHN P. GASSIOT, *Chairman.*

Kew Observatory,
10th September, 1858.

Report of the Parliamentary Committee to the Meeting of the British Association at Leeds, in September 1858.

The Parliamentary Committee have the honour to report as follows:—

That on their representation the late President of the Board of Trade had so far acceded to the suggestions of the President and Council of the Royal Society, supported by the British Association, as to consent to the construction of one Anemometer with Dr. Robinson's Revolving Cups, which would be erected at Bermuda. We believe, however, that another instrument of the same description will be erected at Halifax, at the cost of the Board of Admiralty. These Anemometers are to be constructed on a principle devised by Mr. Welsh of the Kew Observatory, and they will cost about £50 each.

We are happy to be enabled to add, that the late President of the Board of Trade, on a representation made to him by us of the insufficiency of the

Accounts of the Kew Committee of the British Association from Aug. 26, 1857, till Sept. 22, 1858.

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance from last account				171	5	2
Received from the General Treasurer				500	0	0
" for the verification of Instruments—						
from the Board of Trade	22	0	0			
from the Admiralty	37	15	0			
from Opticians	50	5	0			
				110	0	0
				£781	5	2

PAYMENTS.

	£	s.	d.	£	s.	d.
Salaries, &c. :—						
To Mr. Welsh, one year, ending Aug. 27	200	0	0			
Ditto, allowed for petty travelling expenses	10	0	0			
Mr. C. Chambers, five quarters, ending Oct. 6	87	10	0			
Mr. J. V. Magrath, one year, ending Aug. 14	60	0	0			
Mr. Beckley, 56 weeks, ending Sept. 20.	98	0	0			
Mr. G. Whipple, 37 weeks, ending Sept. 20	15	18	0			
				471	8	0
Apparatus, Materials, Tools, &c.				59	6	4
Ironmonger, Carpenter, and Mason				19	13	5
Printing, Stationery, Books, Postage				20	11	0
Coals and Gas				47	10	8
House Expenses, Chandlery, &c.				20	11	8
Porterage and petty expenses				6	12	4
Rent of Land, one year, ending Oct. 10, 1858				21	0	0
Balance in hand				114	11	9
				£781	5	2

I have examined the above account and compared it with the vouchers presented to me, and find the Balance to be One Hundred and Fourteen Pounds Eleven Shillings and Ninepence.

8th Sept. 1858.

R. HUTTON.

accommodations and Staff at the Meteorological Department of the Board of Trade, consented to the appointment of two additional clerks and of a working optician, to be permanently attached to that Department; and, moreover, supplied more enlarged accommodations; so that, upon the whole, Admiral FitzRoy, who so ably presides over this Meteorological Department, expresses himself as satisfied with the present arrangements, and hopeful as to the future success of an institution which cannot fail to be productive of vast benefit to science.

We regret extremely that the application to the Government to send the Expedition to the Mackenzie River was unsuccessful; but we anticipate an important accession to our scientific knowledge from the Expedition to the Zambesi River, which was sanctioned, and sent out under the able conduct of the enterprising and distinguished Livingstone, for this Expedition was well supplied with the necessary instruments properly tested at Kew, and comprises those who are fully competent to use them.

We have been again in correspondence with Mr. Patterson, of Belfast, in reference to the cost of appointments of new Trustees to Museums and other Scientific Institutions. It appears that a clause in the Literary and Scientific Societies' Act, extends the facilities given by the 13 and 14 Vict. c. 28, or the Religious Societies' Act, to Scientific Societies; but that the clause giving such facilities applies to real estate only. There may be some technical difficulties in the way of including personalty, but the subject will not be lost sight of.

The appointment of the Right Hon. Joseph Napier to the office of Lord Chancellor of Ireland, has unhappily caused another vacancy in our body. There are now therefore two vacancies, one of which we recommend should be supplied by the election of the Right Hon. Sir John Pakington, M.P. for Droitwich.

A Memorial having been presented to the Government on the subject of the proposed severance from the British Museum of its Natural History Collections, signed by 114 persons comprising the most eminent promoters and cultivators of science, the same was moved for in the House of Commons by Sir Philip Grey Egerton and produced. We know of no measure which might be adopted by the Government or Legislature, which would inflict a deeper injury on science, than the removal of these Collections, if unhappily carried into effect.

We remain of the same opinion which we expressed in our last Report, that no convenient opportunity has yet occurred to submit to the consideration of the Legislature the twelve Resolutions of the Council of the Royal Society; but we consider that it is difficult to over-estimate the importance of having ascertained and embodied in these Resolutions the opinions of the most distinguished living cultivators of science on its desiderata. They constitute a perpetual record to which reference may always be made by any Member of the Government or Legislature, who is sincerely desirous to promote all such measures as tend to encourage scientific research, and by so doing to advance the most important interests of his country.

WROTTESLEY, *Chairman.*

September 13, 1858.

RECOMMENDATIONS ADOPTED BY THE GENERAL COMMITTEE AT THE LEEDS MEETING IN SEPTEMBER 1858.

[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 Parliamentary Committee, now consisting of

The Lord Wrottesley	Sir Philip Egerton, Bart.
The Earl of Rosse	Right Hon. J. Napier
The Duke of Argyll	Lord Stanley
The Duke of Devonshire	E. J. Cooper, Esq.
The Earl of Enniskillen	Viscount Goderich
The Earl of Harrowby	Sir John Pakington, Bart.,

have authority to expend a sum not exceeding £50 in promoting an Act of Parliament to facilitate the appointment of New Trustees of the Property of Scientific Institutions.

That the sum of £500 be placed at the disposal of the Council for maintaining the Establishment at Kew Observatory.

That a sum of £200 be placed at the disposal of Professor Wilson of the Melbourne University, in aid of his proposed scheme for establishing a Reflecting Telescope, with a speculum of 4 feet diameter, for the Observation of the Southern Nebulæ; on the understanding that the Local Government of Melbourne, Victoria, and other sources, will defray all the remaining cost of carrying the proposal into effect.

That Colonel Sykes, Lord Wrottesley, Professor Faraday, Professor Wheatstone, Dr. Lee, and Professor Tyndall, be appointed a Committee to confer with the Kew Committee as to the expediency of arranging further Balloon Ascents, and (if it should be judged expedient) to carry them into effect; and that a sum of £200 be placed at their disposal, if it should be required for this purpose.

That a Committee, consisting of Professor Maskelyne, Mr. Hardwich, Mr. Llewellyn, and Mr. Hadow, be requested to continue their Researches on the Chemical Nature of the Image formed in Photographic Processes; and that the sum of £10 be placed at their disposal for the purpose.

That Professor Voelcker be requested to continue his Field Experiments and Laboratory Researches on the Constituents of Manures essential to Cultivated Crops; and that the sum of £25 be placed at his disposal for the purpose.

That Professor Sullivan be requested to furnish a Report on the Solubility of Salts at Temperatures above that of Boiling Water, and on the mutual Action of Salts in Solution; and that the sum of £30 be placed at his disposal for the purpose.

That Mr. Alphonse Gages be requested to continue his Experiments on the Chemico-Mechanical Analysis of Minerals; and that the sum of £10 be placed at his disposal for the purpose.

That a Committee, consisting of Sir R. I. Murchison, Mr. Page, and Professor A. C. Ramsay, be requested to direct Mr. Robert Slimmon to pursue his Researches in Developing the Fossil Contents of the Upper Silurian Rocks of Lanarkshire; and that the sum of £20 be placed at their disposal for the purpose.

[The specimens collected to be given in the first place to the Public Museum in Edinburgh; the duplicates to be then presented to the Public

Museum in Jermyn Street, London, and to the Public Museum in Dublin, in connexion with the Geological Survey of the United Kingdom.]

That Mr. Robert Mallet be requested to continue his Experiments on Earthquake Waves at Holyhead; and that the balance of last year's grant of £50 (being a sum of £25) be placed at his disposal for the purpose.

That Mr. Hopkins, Mr. Sorby, Professor A. C. Ramsay, and Mr. Robert Mallet, be requested to conduct a series of Experiments on the Expansion and Contraction of various Rocks by changes of temperature in relation to Physical Geology; and that the sum of £50 be placed at their disposal for the purpose.

That a Committee, consisting of Mr. Robert Patterson, Professor Dickie, Professor Wyville Thomson, Mr. G. C. Hyndman, and Mr. E. Weller, be requested to finish their Report on Dredging in the North and North-east Coasts of Ireland; and that the sum of £20 be placed at their disposal for the purpose.

That Dr. Kinahan, Dr. Carte, Professor J. R. Greene, and Dr. E. P. Wright, be requested to continue their Report on "Dublin Bay Dredging;" and that the sum of £15 be placed at their disposal for the purpose.

That Professor J. R. Greene and Dr. E. P. Wright be requested to finish Professor Greene's Report on British Discoid Medusidæ; and that the sum of £5 be placed at their disposal for the purpose.

That Dr. E. P. Wright and Professor J. R. Greene be requested to draw up a Report on the Irish Tunicata; and that the sum of £5 be placed at their disposal for the purpose.

That Dr. E. P. Wright, Professor J. R. Greene, Dr. Kinahan, and Dr. Carte, be requested to draw up the second part of their Report on the Marine Fauna of the South and West Coasts of Ireland; and that the sum of £10 be placed at their disposal for the purpose.

That a Committee, consisting of Thomas Allis, Sir W. Jardine, Bart., and Mr. T. C. Eyton, be requested to investigate the Osteology and Comparative Anatomy of Birds; and that the sum of £50 be placed at their disposal for the purpose.

That a Committee, consisting of Mr. R. M'Andrew (London), Mr. G. C. Hyndman (Belfast), Dr. Dickie (Belfast), Mr. C. L. Stewart (London), Dr. Collingwood (Liverpool), Dr. Kinahan (Dublin), Mr. J. G. Jeffreys (London), Dr. E. P. Wright (Dublin), Mr. L. Barrett (Cambridge), and Mr. L. Worthy (Bristol), be requested to act as a General Dredging Committee; and that the sum of £5 be placed at their disposal for the purpose.

That a Committee, consisting of Dr. Daubeny and Dr. Lankester, be requested to assist Dr. Voelcker and Professor Buckman in their Researches on the Growth of Plants; and that the sum of £10 be placed at their disposal for the purpose.

That Professor J. Thomson be requested to continue his Experiments on the Measurements of the Discharge of Water through V-shaped Orifices; and that the sum of £10 be placed at his disposal for the purpose.

That the attention of Proprietors of Steam-vessels be called to the great importance of adopting a general and uniform system of recording facts of performances of steam-vessels at sea under all circumstances, and that the following Noblemen and Gentlemen be requested to act as a Committee to carry this object into effect, with £15 at their disposal for the purpose, and to report to the Association at its next Meeting:—Admiral Moorsom; the Marquis of Stafford, M.P.; the Earl of Caithness; Lord Dufferin; Sir James Graham, M.P.; William Fairbairn, F.R.S.; J. S. Russell, F.R.S.; J. Kitson, C.E.; W. Smith, C.E.; J. E. M'Connell, C.E.; C. Atherton, C.E.; Professor Rankine, LL.D.; J. R. Napier, C.E.; Henry Wright (Secretary).

Involving Applications to Government or Public Institutions.

Resolved,—That application be made to the Sardinian Authorities for obtaining additional facilities to scientific men for pursuing their researches on the summits of the Alps.

That the Right Hon. M. T. Baines, M.P., Viscount Goderich, M.P., Mr. Wm. Fairbairn, Mr. James Heywood, General Sabine, and Mr. T. Webster, be appointed a Committee for the purpose of taking such steps as may be necessary to render the Patent System of this country, and the funds derived from inventors, more efficient and available for the reward of meritorious inventors and the advancement of Science.

That a Committee, consisting of Mr. W. Hopkins, Mr. R. Mallet, and General Portlock, be requested to represent to the Meteorological Department of the Board of Trade the desirableness of connecting with its arrangements a system for the observation and record of Oceanic and Littoral Earthquakes and of the occasional occurrence upon the coasts of Great Sea Waves, and, if practicable, of bringing such into immediate operation.

That it is highly desirable that a series of Magnetical and Meteorological Observations on the same plan as those which have been already carried on in the Colonial Observatories for that purpose under the direction of Her Majesty's Board of Ordnance, be obtained, to extend over a period of not more than five years, at the following stations:—

1. Vancouver Island.
2. Newfoundland.
3. The Falkland Isles.
4. Pekin, or some near adjacent station.

That an application be made to Her Majesty's Government to obtain the establishment of Observatories at these stations for the above-mentioned term, on a personal and material footing, and under the same superintendence as in the Observatories (now discontinued) at Toronto, St. Helena, and Van Diemen's Land.

That the observations at the Observatories now recommended, should be comparable with, and in continuation of, those made at the last-named Observatories, including four days of term observations annually.

That provision be also requested at the hands of Her Majesty's Government for the execution within the period embraced by the observations of magnetic surveys in the districts immediately adjacent to those stations, viz. of the whole of Vancouver Island and the shores of the Strait separating it from the main land,—of the Falkland Isles,—and of the immediate neighbourhood of the Chinese Observatory (if practicable), wherever situated,—on the plan of the surveys already executed in the British possessions in North America and in the Indian Archipelago.

That a sum of £350 per annum, during the continuance of the observations, be recommended to be placed by Government at the disposal of the General Superintendent, for the purpose of procuring a special and scientific verification and exact correspondence of the magnetical and meteorological instruments, both of those which shall be furnished to the several Observatories, and of those which, during the continuance of the observations for the period in question, shall be brought into comparison with them, either at Foreign or Colonial Stations.

That the printing of the Observations *in extenso* be discontinued, but that provision be made for their printing in abstract, with discussion, but that the Term Observations, and those to be made on the occurrence of Magnetic Storms, be still printed *in extenso*; and that the registry of the observations be made in triplicate, one copy to be preserved in the office of the General Superintendent, one to be presented to the Royal Society, and one to the Royal Observatory at Greenwich, for conservation and future reference.

That measures be adopted for taking advantage of whatever disposition may exist on the part of our Colonial Governments to establish Observatories of the same kind, or otherwise to cooperate with the proposed system of observation.

That in placing these Resolutions and the Report of the Committee before the President and Council of the Royal Society, the continued cooperation of that Society be requested in whatever ulterior measures may be requisite.

That the President of the British Association be requested to act in conjunction with the President of the Royal Society, and with the Members of the two Committees, in any steps which appear necessary for the accomplishment of the objects above stated.

That an early communication be made of this procedure to His Royal Highness the Prince Consort, the President elect of the British Association for the ensuing year.

That the attention of the Lords Commissioners of the Admiralty be requested to the importance of authorizing further researches on the depth, temperature, and specific gravity of the Sea, more especially in relation to the communications between distant shores by means of Electric Telegraph Cables.

Applications for Reports and Researches.

That Mr. A. Cayley, F.R.S., be requested, in continuation of his Report on the Recent Progress of Theoretical Dynamics, to make a Report on the History of certain special Problems of Dynamics.

That Mr. H. I. S. Smith, M.A., of Balliol College (Oxon), be requested to draw up a Report on the Theory of Numbers.

That Mr. Welsh be requested to draw up an account of the Self-recording Magnetical Instruments at the Kew Observatory, and to present it to the next Meeting of the Association.

That Professor Owen be requested to prepare a Report upon the Crania of the Native Tribes of the Nepal Hills, in his possession, forwarded to him by Mr. Bryan Hodgson.

That Mr. Foster be associated with Dr. Odling to carry out a recommendation of the Dublin Meeting for a Report on Organic Chemistry.

That Dr. Lankester be requested to bring under the notice of the Kew Committee his new Ozonometer.

That the consideration of the Kew Committee be requested to the best means of removing the difficulty which is now experienced by Officers proceeding on Government Expeditions and by other Scientific travellers, in procuring instruments for determinations of Geographical Position, of the most approved portable construction, and properly verified. That the interest of Geographical Science would be materially advanced by similar measures being taken by the Kew Committee in respect to such Instruments, to those which have proved so beneficial in the case of Magnetical and Meteorological Instruments.

Communications to be printed entire among the Reports.

That a Communication by R. H. Meade on the Anatomy of the Spinning Organs of the Araneidæ or true Spiders, be printed in full, and illustrated in the Reports of the British Association.

That a Communication by Mr. Eddy, regarding the Lead Mines of Yorkshire, be printed entire among the Reports.

Synopsis of Grants of Money appropriated to Scientific Objects by the General Committee at the Leeds Meeting in September 1858, with the name of the Member, who alone, or as the First of a Committee, is entitled to draw for the Money.

	£	s.	d.
Parliamentary Committee.			
The Lord Wrottesley.—For promoting an Act of Parliament to facilitate the appointment of New Trustees of the property of Scientific Institutions	50	0	0
Kew Observatory.			
At the disposal of the Council for defraying expenses	500	0	0
Mathematical and Physical Science.			
Wilson, Prof.—Telescope at Melbourne	200	0	0
Sykes, Colonel.—Balloon Ascents	200	0	0
Chemical Science.			
Maskelyne, Prof.—Chemistry of Photography	10	0	0
Voelcker, Prof.—On Constituents of Manures............	25	0	0
Sullivan, Prof.—Solubility of Salts	30	0	0
Gages, Mr. A.—Chemico-Mechanical Analysis of Minerals..	10	0	0
Geology.			
Murchison, Sir R. I.—Fossils in Upper Silurian Rocks	20	0	0
Mallet, R., C.E.—Earthquake Waves	25	0	0
Hopkins, William.—Effect of Temperature on Rocks	50	0	0
Zoology and Botany.			
Patterson, R.—Dredging Coast of Ireland	20	0	0
Kinahan, Dr.—Dredging in Dublin Bay	15	0	0
Greene, Prof.—Report on British Medusidæ............	5	0	0
Wright, Dr. E. P.—Report on Irish Tunicata	5	0	0
Wright, Dr. E. P.—Report on Marine Fauna of Ireland....	10	0	0
Allis, Thomas.—Osteology of Birds	50	0	0
M'Andrew, Robert.—General Dredging	5	0	0
Daubeny, Prof.—Growth of Plants	10	0	0
Mechanical Science.			
Thomson, James, C.E.—Discharge of Water	10	0	0
Moorsom, Admiral.—Performance of Steam Vessels	15	0	0
Total....	£1265	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	3
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 Phænomena	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 Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East coast of Scotland	100	0	0
Revision of the Nomenclature of Stars ... 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3

	£	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 Phænomena	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 Phænomena	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 Phænomena 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 Phænomena	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 Phænomena	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

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, John Taylor, Esq., 6 Queen Street Place, Upper Thames Street, London, 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, Sept. 22, at 8½ P.M., in the Town Hall, The Rev. Humphrey Lloyd, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A., resigned the office of President to Richard Owen, M.D., D.C.L., F.R.S., Corr. Memb. Inst. of France, who took the Chair and delivered an Address, for which see page xlix.

On Thursday Evening, Sept. 23, a Conversazione took place in the Town Hall.

On Friday Evening, Sept. 24, at 8½ P.M., in the Town Hall, John Phillips, M.A., LL.D., F.R.S., Pres. Geol. Soc. of London, delivered a Discourse on the Ironstones of Yorkshire.

On Monday Evening, Sept. 27, at 8½ P.M., The President of the Meeting, Professor Owen, delivered a Discourse on the Fossil Mammalia of Australia.

On Tuesday Evening, Sept. 28, at 8½ P.M., a Conversazione took place in the Town Hall.

On Wednesday, Sept. 29, at 3 P.M., the concluding General Meeting took place in the Town Hall, when the Proceedings of the General Committee, and the Grants of Money for scientific purposes, were explained to the Members.

The Meeting was then adjourned to Aberdeen*.

* The Meeting is appointed to take place on Wednesday, the 14th of September, 1859.

ADDRESS

BY

RICHARD OWEN, M.D., V.P.R.S., D.C.L., F.L.S. ETC.,

SUPERINTENDENT OF THE NATURAL HISTORY DEPARTMENTS, BRITISH MUSEUM.

GENTLEMEN OF THE BRITISH ASSOCIATION,

WE are here met, in this our 28th annual assembly, having accepted, for the present year, the invitation of the flourishing town and firm seat of British manufacturing energy, Leeds, to continue the aim of the Association, which is the promotion of Science, or the Knowledge of the Laws of Nature; whereby we acquire a dominion over Nature, and are able so to apply her powers as to advance the well-being of society and exalt the condition of mankind. It is no light matter, therefore, the work that we are here assembled to do.

God has given to man a capacity to discover and comprehend the laws by which His universe is governed; and man is impelled by a healthy and natural impulse to exercise the faculties by which that knowledge can be acquired. Agreeably with the relations which have been instituted between our finite faculties and the phenomena that affect them, we thus arrive at demonstrations and convictions which are the most certain that our present state of being can have or act upon.

Nor let any one, against whose prepossessions a scientific truth may jar, confound such demonstrations with the speculative philosophies condemned by the Apostle; or ascribe to arrogant intellect soaring to regions of forbidden mysteries the acquisition of such truths as have been or may be established by patient and inductive research. For the most part, the discoverer has been so placed by circumstances, rather than by predetermined selection, as to have his work of investigation allotted to him as his daily duty; in the fulfilment of which he is brought face to face with phenomena into which he must inquire, and the result of that inquiry he must faithfully impart. The course of natural as of moral truth is progressive: but it has pleased the Author of all truth to vary the fashion of the imparting of such parcels thereof as He has allotted from time to time, for the behoof and guidance of mankind.

Those who are privileged with the faculties of discovery are, therefore, to be regarded as preordained instruments in making known the power of God, without a knowledge of which, as well as of Scripture, we are told that we shall err.

Great and marvellous have been the manifestations of this power imparted to us of late times, not only in respect of the shape, motions, and solar relations of the earth, but also of its age and inhabitants.

In regard to the period during which the globe allotted to man has revolved in its orbit, present evidence strains the mind to grasp such sum of past time with an effort like that by which it tries to realize the space dividing that orbit from the fixed stars and remoter nebulæ. Yet, during all those æras that have passed since the Cambrian rocks were deposited which bear the impressed record of Creative power, as it was then manifested, we know, through the interpreters of these 'writings on stone,' that the earth was vivified by the sun's light and heat, was fertilized by refreshing showers, and washed by tidal waves.

No stagnation has been permitted to air or ocean. The vast body of waters not only moved, as a whole, in orderly oscillations, regulated, as now, by sun and moon; but were rippled and agitated by winds and storms. The atmosphere was healthily influenced by its horizontal currents; and by ever-varying clouds and vapours, rising, condensing, dissolving, and falling in endless vertical circulation. With these conditions of life, we know that life itself has been enjoyed throughout the same countless thousands of years; and that with life, from the beginning, there has been death.

The earliest testimony of the living thing, whether shell, crust, or coral in the oldest fossiliferous rock, is at the same time proof that it died.

At no period has the gift of life been monopolized by a few contemporary individuals through a stagnant sameness of untold time; but it has been handed over from generation to generation, and successively enjoyed by the myriads that constitute the species. And, herein, we discern the greater beneficence and wisdom; that, through death, whether sudden or preceded by a brief decay, the individual enjoys the varying phases of life,—healthy assimilative growth, active youth, and vigorous maturity, with the procreative faculties and instincts to boot. And as life rises in the scale, even to the present highest form, foreknowing of his end, death is still the condition on which are enjoyed man's purest pleasures,—the reverential love of parents—the holy affections of wedlock—the fond yearning towards offspring.

It has further been given us to know, that not only the individual but the species perishes; that as death is balanced by generation, so extinction has been concomitant with creative power, which has continued to provide a succession of species; and furthermore, that, as regards the varying forms of life which this planet has witnessed, there has been "an advance and progress in the main."

Geology demonstrates that the Creative force has not deserted this earth during any of her epochs of time; and that in respect to no one class of animals has the manifestation of that force been limited to one epoch. Not a species of fish that now lives, but has come into being during a comparatively recent period: the existing species were preceded by other species, and these again by others still more different from the present. No existing genus of fishes can be traced back beyond a moiety of known creative time. Two entire orders have come into being, and have almost superseded two other orders since the newest of the secondary formations of the earth's crust.

The axiom of the continuous operation of Creative power, or of the ordained becoming of living things, is here illustrated by the class of fishes, because that class is exempt from the application of some exterminating causes affecting terrestrial and air-breathing animals.

But the creation of every class of such animals, whether Reptiles, Birds, or Beasts, has been successive and continuous, from the earliest times at which we have evidence of their existence. The reptiles of the coal measures, the great birds that impressed the Connecticut sandstones, and the marsupial mammals of the Stonesfield and Purbeck Oolites, came into being long before the Cycloid fishes were created and anterior to the apparition of any known existing species of aquatic animal. Species after species of land animals, order after order of air-breathing reptiles, have succeeded each other; creation ever compensating for extinction. The successive passing away of air-breathing species may have been as little due to exceptional violence, and as much to natural law, as in the case of marine plants and animals. It is true, indeed, that every part of the earth's surface has been submerged; but successively, and for long periods. Of the present dry land different natural continents have different faunæ and floræ; and the fossil remains of the plants and animals of these continents respectively show that they possessed the same peculiar characters, or characteristic *facies*, during periods extending far beyond the utmost limits of human history.

Such, gentlemen, is a brief summary of facts most nearly interesting us, which have been demonstratively made known respecting our earth and its inhabitants. And when we reflect at how late and in how brief a period of historical time the acquisition of such knowledge has been permitted, we must feel that, vast as it seems, it may be but a very small part of the patrimony of truth destined for the possession of future generations.

The certain knowledge of the very shape of the earth dates not so far back by some centuries as that epoch marked by the revelation, amongst other divine truths, of the responsibility of man for the use of the talent entrusted to him; and we may well believe that it has been mainly under the sense of this responsibility that men have submitted themselves to that patient endurance of the labour of investigation, experiment, comparison, invention, and the pondering on results, often to the utmost reach of mental tension, by which the present knowledge of the Divine power has been acquired.

In reviewing the nature and results of our proceedings during the last twenty-seven years, and the aims and objects of our Association, it seems as if we are realizing the grand Philosophical Dream or Prefigurative Vision of Francis Bacon, which he has recounted in his 'New Atlantis.'

In this noble Parable the Father of Modern Science imagines an Institution which he calls "Solomon's House," and informs us, by the mouth of one of its members, that "the end of its Foundation is the Knowledge of Causes and Secret Motions of Things; and the enlarging of the bounds of Human Empire to the effecting of all things possible."

Amongst the means and instruments to this great end, Bacon imagines laboratories situated at the greatest attainable distances, vertically, in regard to the atmosphere;—some sunk 600 fathoms deeper than the deepest natural cave; others placed on towers set upon high mountains, "so that the vantage of the hill with the tower is in the highest of them three miles at least." In the depths he conceives might be carried on the producing of new artificial metals* by compositions and materials left at work for many years, in imitation of natural mines; also observations on the formation of figured fossils; and he speculates upon the influence of these cold depths in the curing of certain diseases and the prolonging of human life, as it seems by a superinduced torpidity. In the higher regions of the air are to be carried on observations of the heavens, and of divers meteors—wind, rain, hail, and falling stars.

"We have also," he writes, "spacious houses where we imitate and demonstrate meteors, as thunders, lightnings, snow, hail, and rain. We have, also, instruments which generate heat only by motion."

Next come arrangements for the appliance of water-power and of winds to set a-going divers motions:—"engine-houses, where are prepared engines and instruments for all sorts of motions, some swifter than any known to the rest of the world, and other various motions for equality, fineness and subtilty:—a mathematical house, where are represented all instruments, as well of geometry as astromomy, exquisitely made. We have also sound-houses, where we practise and demonstrate all sounds and their generation, as by divers instruments of music; and those that imitate all articulate sounds and letters, and the voices and notes of beasts and birds. We have also the means to convey sounds in trenches and pipes in strange lines and distances." Then come the perspective-houses, "where we make demonstrations of all light and radiations and of all colours; and out of things uncoloured and transparent we can represent unto you several colours, both as rainbows and as single. We make artificial rainbows, halos and circles about light, and represent all manner of reflexions, refractions, and multiplication of visual beams of objects. These multiplications of light we carry to great distances, and make so sharp as to discern small points and lines. We procure means of seeing objects afar off, as in the heaven and remote places, representing things afar off as near. We

* Davy, Herschel, Aluminium.

have also glasses and means to see minute bodies perfectly and distinctly, as the shapes and colours of small flies and worms, which cannot otherwise be seen;" also "observations on blood and sap not otherwise to be seen."

In regard to natural history, Bacon imagines huge Aquaria, of both salt and fresh water, for the use and observation and generation of fish and fowl, "where we make trials upon fishes. We have also parks and enclosures of all sorts of beasts and birds, which we use not only for view and rareness, but likewise for dissections and trials; that thereby we may take light what may be wrought upon the body of man.

"We have also large and various orchards and gardens, wherein we do not so much respect beauty as variety of ground and soil: in these are practised all conclusions of grafting and inoculating; and we make, by art, trees and flowers to come up earlier or later than their seasons; we also make them by art much greater than their nature, and their fruit greater and sweeter, and of different taste, smell, and colour."

Lastly, as one important means of effecting the great aims of the "six days-college," certain of its members were deputed, as "merchants of light," to make "circuits or visits of divers principal cities of the kingdom."

This latter feature of the Baconian organisation is the chief characteristic of the "British Association;" but we have striven to carry out other aims of the 'New Atlantis,' such as the systematic summaries of the results of different branches of science, of which our published volumes of 'Reports' are evidence; and we have likewise realized, in some measure, the idea of the 'Mathematical House' in our establishment at Kew.

The national and private Observatories, the Royal and other Scientific Societies, the British Museum, the Zoological, Botanical, and Horticultural Gardens combine in our day to realize that which Bacon foresaw in distant perspective. Great beyond all anticipation have been the results of this organisation, and of the application of the inductive methods of interrogating Nature.

The universal law of gravitation, the circulation of the blood, the analogous course of the magnetic influence, which may be said to vivify the earth, permitting no atom of its most solid constituents to stagnate in total rest; the development and progress of Chemistry, Geology, Palæontology; the inventions and practical applications of gas, the steam-engine, photography, telegraphy:—such, in the few centuries since Bacon wrote, have been the rewards of the faithful followers of his rules of research.

We can hardly appreciate the swift of progress of human knowledge unless we go back, for an instant, to the period whice I have chosen as the starting-point in this survey.

Bacon's treatment of the Copernican theory shows the importance of pure observation in the establishment of natural truth, and places in a strong light the incompetency of the highest intellectual power, of itself, to reason up to truth, even when it is so plain as it now appears to us in reference to the true nature of the apparent movements of the sun in respect to the earth.

The well-known passages from the 'Thema Cœli,' and the essay 'On the

Cause of the Tides,' together with the fling "at those few carmen which drive the earth about*," are strongly indicative of the state of Bacon's mind —the philosophical mind of his time—on the great question then agitating it, as to the movements of the heavenly bodies.

A mass of observations of their apparent movements had been accumulating from the periods of Hipparchus and Ptolemy to that of Copernicus. The nature and cause of those observed movements had to be explained. The Alexandrian astronomer had given an explanation in harmony with the apparent motions. Copernicus suggested another, contradictory of the apparent motions, but more in harmony, through certain reasons assigned, with what he believed to be their real nature.

These reasons wanted proofs from observation; but the proofs afterwards came, and were the fruit of the more commonly possessed inventive faculty rather than of the rarer power of abstract thought. Great, truly, is the gift to mankind when the two faculties coexist in a commanding intellect!

Galileo invented a perspective glass by which he discovered the four small bodies which revolve about Jupiter in different periods of time. The analogy which this visible system of Jupiter bore to the solar system, as conceived by Copernicus, gave what Herschel calls the "holding turn" to the opinions of mankind respecting the heliocentric system. Galileo's next discovery more decidedly confirmed the truth of that system. He observed that Venus in the course of her revolution assumed the same succession of phases which our moon exhibits in her monthly circuit. The opponents of Copernicus had objected that Venus did not appear four times as large as she should do when, according to his system, she is four times as near us; but Galileo furnished the true reason: the dark side of Venus is toward the earth when she is nearest it. But with all this, Bacon's acceptance of the Copernican system never went further than as respected the movements of Venus and Mercury about the Sun.

My motive in here referring to such trite facts in the History of Astronomy is to impress upon all who sympathize with scientific progress, or merely wish us 'good speed,' the importance of direct observation of Nature. The two results of Galileo's direction of his telescope to heavenly bodies were of more value than the subtlest of the objections of Bacon or of the excuses of Bruno.

In 1631 Kepler witnessed the transit of Mercury across the sun's disk: in 1639 Horrox saw the like transit of Venus: and these observations were of a higher kind than Galileo's. His might be called a chance trial of the phenomena of the skies; the English astronomer planted his telescope at the very hour, when, according to the Copernican hypothesis, he had calculated that Venus in her orbit would pass between the sun and the earth. Kepler's observation of the elliptical form of the orbit of Mars definitely cast out the eccentrics and epicycles of Ptolemy, and made the Copernican explanation easier than it had seemed to Copernicus himself.

* Discourse 'In Praise of Knowledge.'

The motions of the heavenly bodies being thus determined, there remained their cause, or their laws. Kepler's successive approximations to an accurate determination of the orbits of the planets, and to the ratios of their mean distances from the sun to the times of their revolutions, which mathematicians now express by saying that "the squares of the periodic times are in the same proportion as the cubes of the distance," became an important prelude to Newton's discovery of the law of the sun's attractive force.

Without stopping to trace the concurrent progress of the science of motion, of which the true foundations were laid, in Bacon's time, by Galileo, it will serve here to state that the foundations were laid and the materials gathered for the establishment, by a master-mind, supreme in vigour of thought and mathematical resource, of the grandest generalization ever promulgated by science—that of the universal gravitation of matter according to the law of the inverse square of the distance.

The same century in which the 'Thema Cœli' of Lord Verulam and the 'Nuncius Sidereus' of Galileo saw the light, was glorified by the publication of the 'Philosophiæ Naturalis Principia Mathematica' of Newton.

Has time, it may be asked, in any way affected the great result of that masterpiece of human intellect? There are signs that even Newton's axiom, or the terms in which it was enunciated, may not be exempt from the restless law of progress.

The mode of expressing the law of gravitation as being "in the inverse proportion of the square of the distances," involves the idea that the force emanating from or exercised by the sun must become more feeble in proportion to the increased spherical surface over which it is diffused. So, indeed, it was expressly understood by Halley.

The ablest historian of Natural Science has remarked that "future discoveries may make gravitation a case of some wider law, and may disclose something of the mode in which it operates*." The difficulty, indeed, of conceiving a force acting through nothing from body to body has of late made itself felt; and more especially since Meyer of Heilbron first clearly expressed the principle of the 'conservation of force.' Newton, though apprehending the necessity of a medium by which the force of gravitation should be conveyed from one body to another†, yet appears not to have possessed such an idea of the indestructibility of force as that which, now possessed by minds of the highest order, seems to some of them to be incompatible with the terms in which Newton enunciated his great law; viz. of matter attracting matter with a force which varies inversely as the square of the distance.

Faraday has offered the following comment on this received expression of the idea of gravity:—"Assume two particles of matter, A and B, in free space, and a force in each or in both by which they gravitate

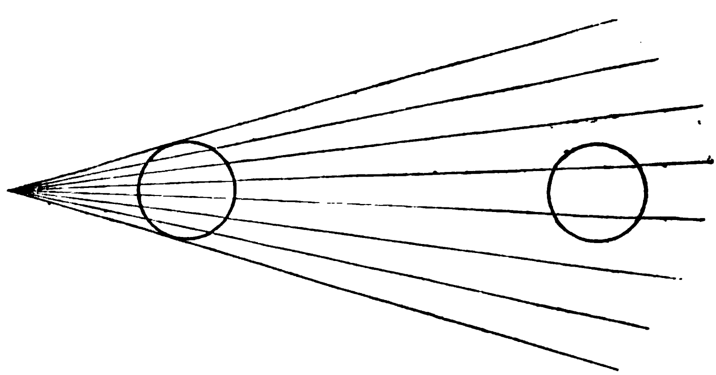
* Whewell, History of the Inductive Sciences.

† See Newton's Third Letter to Bentley.

towards each other, the force being unalterable for an unchanging distance, but varying inversely as the square of the distance, when the latter varies. Then, at the distance of 10 the force may be estimated as 1; whilst at the distance of 1, *i. e.* one-tenth of the former, the force will be 100: and if we suppose an elastic spring to be introduced between the two as a measure of the attractive force, the power compressing it will be a hundred times as much in the latter case as in the former. But from whence can this enormous increase of the power come? If we say that it is the character of this force, and content ourselves with that as a sufficient answer, then, it appears to me, we admit a *creation* of power, and that to an enormous amount; yet by a change of condition, so small and simple as to fail in leading the least-instructed mind to think that it can be a sufficient cause, we should admit a result which would equal the highest act our minds can appreciate of the working of infinite power upon matter; we should let loose the highest law in physical science which our faculties permit us to perceive, namely, the *conservation of force.* Suppose the two particles A and B removed back to the greater distance of 10, then the force of attraction would be only a hundredth part of that they previously possessed; this, according to the statement that the force varies inversely as the square of the distance, would double the strangeness of the above results; it would be an *annihilation* of force: an effect equal in its affinity and its consequences with *creation*, and only within the power of Him who has created."

If we suppose the different modes of force, which we call 'light,' 'heat,' 'gravity,' to act in all directions, as emanations from a centre, with a force which is the same in every part of the line, throughout space, the law of the 'inverse squares' would be a necessary consequence of the fact that, at double the distance, only one-fourth the number of such 'lines of force' would impinge or act upon the 'illuminated,' 'heated' or 'attracted' body *.

This may be understood by the subjoined diagram:—



* Westminster Review, No. XXVII.

So much in illustration of the present phase of scientific thought in reference to the Newtonian axiom.

The progress of knowledge of the form of all-pervading force, which we call, from its most notable effect on one of the senses, 'light,' has not been less remarkable than that of gravitation.

Galileo's discovery of Jupiter's satellites supplied Römer with the phenomena whence he was able to measure, in 1676, the velocity of light. Descartes, in his theory of the Rainbow, referred the different colours to the different amount of refraction, and made a near approximation to Newton's capital discovery of the different colours entering into the composition of the luminous ray, and of their different refrangibility. Hook and Huyghens, about the same period had entered upon explanations of the phenomena of light conceived as due to the undulations of an ether, propagated from the luminous point spherically, like those of sound. Newton, whilst admitting that such undulations or vibrations of an ether would explain certain phenomena, adopted the hypothesis of emission as most convenient for the mathematical propositions relative to light. The discoveries of achromatism, of the laws of double refraction, of polarization circular and elliptical, and of depolarization, rapidly followed, realizing more than Bacon conceived might flow from the labours of the 'perspective house,' and, with later advances in optics, have made renowned the names of Dollond, Young, Malus, Fresnel, Arago, Biot, Brewster, Stokes, and Jamin.

Some of the natural sciences, as we now comprehend them, had not germinated in Bacon's time. Chemistry was then Alchemy: Geology and Palæontology were undreamt of: but Magnetism and Electricity had begun to be observed, and their phenomena compared and defined by a contemporary of Bacon, in a way that claims to be regarded as the first step toward a scientific knowledge of those powers. It is true that, before Gilbert*, the magnet was known to attract iron, and the great practical application of magnetized iron—the mariner's compass—had been invented, and for many years before Bacon's time had guided the barks of navigators through trackless seas.

Gilbert, to whom the name 'electricity' is due, observed that that force attracted light bodies, whereas the magnetic force attracted iron only. About a century later the phenomena of repulsion as well as of attraction of light bodies by electric substances were noticed; and Dufay, in 1733, enunciated the principle that "electric bodies attract all those that are not so, and repel them as soon as they are become electric by the vicinity of the electric body."

The conduction of electric force, and the different behaviour of bodies in contact with the electric, leading to their division, by Desaguliers, into conductors and non-conductors, next followed. The two kinds of electricity, at first by Dufay, their definer, called 'vitreous' and 'resinous,' afterwards, by

* De Magnete (1600).

Franklin, 'positive' and 'negative,' formed an important step, which led to a brilliant series of experiments and discoveries, with inventions, such as the Leyden jar, for intensifying the electric shock. But whilst the majority of the applications of these degrees of mastery over the electric force was calculated to amuse or surprise, the instantaneous transmission of electricity through an extent of 6000 feet, demonstrated by Sir W. Watson, together with Franklin's discovery of the electric state of the clouds, and of the power of drawing off such electricity by pointed bodies, was a brilliant beginning of the application of this subtle science to the discovery of the well-being and needs of mankind. Superstitious ignorance might well shrink from playing, as the American philosopher with his electric kites seemed to be doing, with lightning,—might gaze with alarm at the Russian Professor * collecting on his electrical rod the awful charge of the black thunder-cloud,—might deem the globe of fire which leapt from the rod upon the head of the experimenter and struck him dead as a judgment for tampering with a force that man's instinct, in all ages, has referred to a direct expression of the power and will of Deity. But the cultivator of God's intellectual gifts sees rather, in the application of the lightning-conductors which now guide harmless to the earth the dangerous electricity of the clouds, the predestined fruit and reward of the laborious and dauntless application of those gifts, agreeably with the rule of right reason, to the unfolding of natural phenomena.

To hide from the lightning and tremble at the thunder, as the immediate manifestation of offended Deity, is the superstition of the savage: to recognize that both phenomena are under the control of a law, and operating to beneficial ends, is the privilege of the sage. This it is which begets a true and worthy feeling of reverence for the Lawgiver.

When the knowledge of the law gives the mode of diverting from the well-manned ship and the crowded hall the destructive influence of the electric bolt, we then worthily adore the beneficence that has imparted so much of the power-interpreting talent as brings that reward for its enjoined use. The philosopher, in the course of his hazardous experimental researches, may incur a fatal result; but he becomes then, not the sacrifice for presumptuous espial into divine and forbidden mysteries, but the true 'martyr of science.' His death has contributed to save the lives of thousands of his fellow-creatures and to allay the distressing fears of millions.

Magnetism has been studied with two aims,—the one to note the numerical relations of its activity to time and space, both in respect of its direction and intensity, the other to penetrate the mystery of the nature of the magnetic force.

In reference to the first aim, my estimable predecessor adverted, last year, to the fact that it was in the Committee-rooms of the British Association that the first step was taken towards that great magnetic organization which has since borne so much fruit. Thereby it has been determined that there

* Richmann.

are periodical changes of the magnetic elements depending on the hour of the day, the season of the year, and on what seemed strange intervals of about eleven years. Also, that besides these regular changes there were others of a more abrupt and seemingly irregular character—Humboldt's 'magnetic storms'—which occur simultaneously at distant parts of the earth's surface. Major-General Sabine, than whom no individual has done more in this field of research since Halley first attempted "to explain the change in the variation of the magnetic needle," has proved that the magnetic storms observe diurnal, annual, and decennial periods. But with what phase or phenomenon of earthly or heavenly bodies, it may be asked, has the magnetic period of ten years to do? The coincidence which points to, if it does not give, the answer, is one of the most remarkable, unexpected, and encouraging to patient observers.

For thirty years a German astronomer, Schwabe, had set himself the task of daily observing and recording the appearance of the sun's disk; in which time he found that the spots passed through periodic phases of increase and decrease, the length of the period being about ten years. A comparison of the independent evidence of the astronomer and magnetic observer has shown that the decennial magnetic period coincides both in its duration and in its epochs of maximum and minimum with the same period observed in the solar spots.

A few weeks ago, during a visit of inspection to our establishment at Kew, I observed the successful operation of the photoheliographic apparatus in depicting the solar spots as they then appeared. The continued regular record of the macular state of the sun's surface, with the concurrent magnetic observations now established over many distant points of the earth's surface, will ere long establish the full significance and value of the remarkable, and, in reference to the observers, undesigned, coincidence above mentioned.

Not to trespass on your patience by tracing the progress of magnetism from Gilbert to Oersted, I cannot but advert to the time, 1807, when the latter tried to discover whether electricity in its most latent state had any effect on the magnet, and to his great result, in 1820, that the conducting-wire of a voltaic circuit acts upon a magnetic needle, so that the latter tends to place itself at right angles to the wire.

The ablest physicists in Europe, and Ampère especially, devoted themselves, immediately on the promulgation of this capital discovery, to the analysis of its conditions. Ampère, moreover, succeeded, by means of a delicate apparatus, in demonstrating that the voltaic wire was affected by the action of the earth itself as a magnet. In short, the generalization was established, that *magnetism and electricity are but different effects of one common cause.* This has proved the first step to still grander abstractions—to that which conceives the reduction of all the species of imponderable fluids of the chemistry of our student days, together with gravitation, chemicity*,

* 'Elective' or 'molecular attraction.'

and neuricity*, to interchangeable modes of action of one and the same all-pervading life-essence.

Galvani arranged the parts of a recently-mutilated frog so as to bring a nerve in contact with the external surface of a muscle, when a contraction of the muscle ensued. In this suggestive experiment the Italian philosopher, who thereby initiated the inductive inquiry into the relation of nerve force to electric force, concluded that the contraction was a necessary consequence of the passage of electricity from one surface to the other by means of the nerve. He supposed that the electricity was secreted by the brain, and transmitted by the nerves to different parts of the body, the muscles serving as reservoirs of the electricity. Volta made a further step, by showing that, under the conditions or arrangements of Galvani's experiments, the muscle would contract, whether the electric current had its origin in the animal body, or from a source external to that body. Galvani erred in too exclusive a reference of the electric force producing the contraction to the brain of the animal: Volta in excluding the origin of the electric force from the animal body altogether. The determination of 'the true' and 'the constant' in these recondite phænomena has been mainly helped on by the persevering and ingenious experimental researches of Matteucci and Du Bois Reymond. The latter has shown that any point of the surface of a muscle is positive in relation to any point of the divided or transverse section of the same muscle; and that any point of the surface of a nerve is positive in relation to any point of the divided or transverse section of the same nerve. Mr. Baxter, in still more recent researches, has deduced important conclusions on the origin of the muscular and nerve currents, as being due to the polarized condition of the nerve or muscular fibre, and the relation of that condition to changes which occur during nutrition. From the present state of neuro-electricity it may be concluded that nerve force is not identical with electric force, but that it may be another mode of motion of the same common force: it is certainly a polar force, and perhaps the highest form of polar force:—

> "A motion which may change, but cannot die;
> An image of some bright eternity."

The present tendency of the higher generalizations of chemistry seems to be toward a reduction of the number of those bodies which are called 'elementary;' it begins to be suspected that certain groups of so-called chemical elements are but modified forms of one another.

An important step in the elimination of the chlorine and bromine group from the category of simple bodies or elements has very recently been made by Prof. Schönbein. He, at least, adduces strong reasons, from analogy, for regarding those substances as 'oxy-compounds,' or what the Professor terms 'Ozonides;' chlorine being, according to this view, the peroxide of murium$=MuO+\Theta$. The researches on which this conclusion is founded have recalled to my mind the cautious terms in which my venerable Teacher

* Force ascribed to a nervous fluid.

of Chemistry, HOPE, always introduced Davy's then new hypothesis; and I now better appreciate the celebrated Edinburgh Professor's disinclination to abandon the old doctrine of the compound nature of chlorine, &c.

Organic chemistry becomes simplified as it expands; aud its growth has, of late, proceeded, through the labours of Hoffmann, Berthelot, and others, with unexampled rapidity. The results of the recent experiments of M. Berthelot have more especially tended to reduce the various and numerous ternary oxygenated organic substances into a small number of fundamental groups. The important power of synthesis has grown with this growth. Since Wöhler, in 1828, succeeded in artificially producing 'urea,' Kolbe has similarly, by the combinations of inorganic elements, produced acetic acid and the new organic radical 'methyl.' Berthelot has formed glycerine, the basis of animal and vegatable oils and fats, and has also formed grape-sugar. It is true, that in the latter synthesis the contact of putrefying animal matter is requisite; although such matter contributes none of its constituents to the new compound, nor undergoes any appreciable change in the process. Berthelot has very recently shown that cholesterine is a true alcohol, analogous to éthal; and that, treated by acids, it is transformed into corresponding ethers, similar to other éthilic ethers.

A substance resembling camphor has been this year made by the action of acids, *e.g.*, the chorhydric, upon essential oil of turpentine. By treating this substance with strong alkali it is changed into a liquid carburet of hydrogen; but, if feeble alkalis are employed or slightly alkaline salts, a solid carburet is obtained identical with camphor. By oxidizing the artificial camphor, ordinary camphor is obtained; by adding hydrgoen to such ordinary camphor, the camphor of Borneo is obtained. M. Berthelot has thus realized the synthetic preparation of camphors.

An important series of alcohols and their derivatives, from amylic alcohol downwards; as extensive a series of ethers, including those which give their peculiar flavour to our choicest fruits; the formic, butyric, succinic, lactic, and other acids, together with other important organic bodies, are now capable of artificial formation from their elements, and the old barrier dividing organic from inorganic bodies is broken down. To the power which mankind may ultimately exercise through the light of synthesis, who may presume to set limits! Already natural processes can be more economically replaced by artificial ones in the formation of a few organic compounds, the 'valerianic acid,' for example. It is impossible to foresee the extent to which Chemistry may not ultimately, in the production of things needful, supersede the present vital agencies of nature "by laying under contribution the accumulated forces of past ages, which would thus enable us to obtain in a small manufactory, and in a few days, effects which can be realized from present natural agencies, only when they are exerted upon vast areas of land, and through considerable periods of time*."

* Frankland, Lecture, Royal Institution, May 28, 1858.

Since Nièpce, Herschel, Fox Talbot, and Daguerre laid the foundations of Photography, year by year some improvement is made, some advance achieved, in this most subtle application and combination of discoveries in Photicity, Electricity, Chemistry, and Magnetism.

Last year M. Poiteven's production of plates in relief, for the purpose of engraving by the action of light alone, was cited as the latest marvel of photography. This year has witnessed photographic printing in carbon. M. Pretschi's method is as follows:—

"A photograph or engraving is placed on the prepared plate, and a negative taken in sun-light. The glass is then placed in water with a little alcohol, and the darkened parts are rendered soluble, while the other parts are insoluble, so that in a few minutes we have a picture represented not only by light and shadow, but by the unequal thickness of the gelatine on the glass. When the plate is dry, soft gutta-percha is pressed upon the picture till it hardens. The gutta-percha has consequently an image the reverse of the first. After rubbing it over with bronze powder or black-lead, it is placed in a solution of sulphate of copper, and an electrotype plate taken from it, in the usual way, with a voltaic battery. From this plate others can be readily taken, and, as in ordinary copperplate printing, thousands of copies can be thrown off. 'By this process,' says Mr. Hunt, 'pictures, in which the most delicate details are very faithfully preserved, and the nice gradations in light and shadow maintained in all their beauty, are now printed from the electrotype plate, obtained from the photograph. The process of photo-galvanography is evidently destined to take a very high position as a means of preserving the beauties of nature and art.'"

M. Nièpce de St. Victor has succeeded in reproducing the colour of the original on metallic plates; though he cannot fix it. Unfortunately these lovely 'heliochromes' vanish like the breath from the mirror.

M. Delarue has obtained photographs of the moon in which the details of its illuminated surface are well defined—the cone in 'Tycho,' the double cone in 'Copernicus,' and even the ridge of 'Aristarchus.' A photograph of the planet Jupiter has been obtained in which the belts are very well marked and the satellites distinct.

The portrait of a 13-inch shell has been secured while in full flight, a few feet after it left the mortar; and, in effecting this, Mr. Scaife has obtained a representation of phenomena in the development of the smoke too transitory for the eye to ascertain when they occur. The photographic eye is, in fact, more sensitive than the living one: it can receive and register impressions too fine for human vision, until made visible by increased light and developing agents. Hence, photography may superadd a new defining function to the highest attainable telescopic power.

Photography is now a constant and indispensable servant in certain important meteorological records. Applied periodically to living plants, photography supplies the botanist with the easiest and best data for judging of their rate of growth. It gives to the zoologist accurate representations of the most complex of his subjects, and of their organization, even to microscopic details.

The engineer at home can ascertain by photographs transmitted by successive mails the weekly progress, brick by brick, board by board, nail by nail, of the most complex works on the Indian or other remote rail-roads. The physician can register every physiognomic phase accompanying the access, height, decrease, and passing away of mental disease.

The humblest emigrant may carry with him miniatures, such as Dow could not have equalled in the perfection of their finish, of scenes and persons which will recall and revive the dearest affections of the home he has left.

In its lowest application photography becomes an instrument of the criminal police.

The first practical application of the electro-magnetic discovery was, as it should be, to the direct service of the philosophic inquirer: it was such an application of a delicate compass-needle as would show, by its deflection, the strength of the voltaic current. The possession of Schweigger's 'galvanometer' enabled the philosopher henceforth to detect and measure the minutest electro-dynamic actions. It led to the discovery by Seebeck of the conversion of heat into that kind of action; in short, of thermo-electricity.

On Faraday's demonstration—the converse of Oersted's—that magnetism could produce electricity, and on the brilliant series of discoveries of that most exemplary investigator of natural laws, I need not dwell, in the presence of so many who are better qualified than myself to comprehend and illustrate them.

Remote as such profound conceptions and subtle trains of thought seem to be from the needs of every-day life, the most astounding of the practical augmentations of man's power has sprung out of them. Nothing might seem less promising of profit than Oersted's painfully-pursued experiments, with his little magnets, voltaic pile, and bits of copper-wire. Yet out of these has come the electric telegraph! Oersted himself saw such an application of his convertibility of electricity into magnetism; and Schilling successfully applied the principle to the instantaneous communication of signs through distances of a few miles. The unrivalled resources of Wheatstone's inventive genius have made it practicable for all distances, as we have lately seen in the submergence and working of the electro-magnetic cord connecting the Old with the New World.

Whoever has been engaged in the delicate physical and chemical experiments required in the present state of natural philosophy, will know how small is the expectation of success on the first trial of a new experiment in the laboratory. Only the experienced manipulator realizes how hard it is to foresee every condition requisite for success: but it is he who bears the bravest heart under failures, well assured that through them are acquired the conditions of success, and that every cause of failure, well ascertained, is an encouragement to the repetition of the trial. Every practical physicist, therefore, was prepared to expect a certain number of instructive failures in the attempt to carry out the grandest philosophical experiment on record—the most stupendous which mortal mind ever ventured to propose to itself. Our surprise is, that the failures were so few,—the success so speedy. But the persevering and determined men who achieved this success, temporary as it has been, were animated by the spirit in which Lord Bacon tells us experimental philosophy should be entered upon:—"For there is no comparison," he writes, "between that which we may lose by not trying and by not succeeding; since by not trying we throw away the chance of an immense good, by not succeeding we only incur the loss of a little human labour."

On the 6th of August, 1858, the laying down of upwards of 2000 nautical miles of the telegraphic cord, connecting Newfoundland and Ireland, was successfully completed; and shortly after, a message of thirty-one words was transmitted in thirty-five minutes along the sinuosities of the submerged hills and valleys forming the bed of the great Atlantic. This first message ended by expressing—"GLORY TO GOD IN THE HIGHEST: ON EARTH PEACE, GOODWILL TOWARDS MEN." Never since the foundations of the world were laid could it be more truly said, "The depths of the sea praise Him!"

More remains to be done before the far-stretching, thought-bearing engine can be got into full working order; but the capital fact, viz., the practicability of bringing America into electrical communication with Europe has been demonstrated; consequently a like power of instantaneous interchange of thought between the civilized inhabitants of every part of the globe becomes only a question of time. The powers and benefits thence to ensue for the human race can be but dimly and inadequately foreseen. Some results stand out more prominently than others.

The investigator of natural laws manifests his success by the degree in which he elicits and substitutes latent natural force for manual labour in effecting his purpose. Sennacherib, as we see on the slabs from Nineveh, added the lever to traction in the transport of the colossal symbolic statues of his majesty; but the power by which he worked both mechanical adjustments was slaves stimulated by the stick. Hundreds of human beings were sacrificed in the operation. WATT achieved an equal effect by the scientific eduction and direction of the latent force contained in a few pounds of coal.

If this test be applied to the present state of the science of governing peoples, it would seem to show but little progress therein. The conscription committee of France for 1858 proposed a levy of 100,000 men, because less would not suffice to keep up the requisite army of 500,000 men; Europe being at peace. Even the United States of America have progressively increased their standing army to a present total of 17,000 men.

The probability of a further augmentation of the military force of the Federal Government, in reference to a possible rupture with the Mother-country, must be greatly diminished by an ocean telegraph. And we may confidently hope that this and other applications of pure science will tend to abolish wars over the whole earth; so that men may come to look back upon the trial of battle between misunderstanding nations, as a sign of a past state of comparative barbarism; just as we look back from our present phase of civilization in England upon the old border-warfare.

Bacon, commenting on the History of the Works of Nature, as it presented itself to him, describes it as a chaos "of fables, antiquities, quotations, frivolous disputes, philology, ornaments, and table-talk." Since his day the chief steps, by which Natural History has advanced to the dignity of a science, are associated with the names of Ray, Linnæus, Jussieu, Buffon, and Cuvier.

By the two former the phenomena were digested and classified, according to artificial but conveniently applicable methods; of necessity the precursors of systems more expressive of the natural affinities of plants and animals.

To perfect the natural system of plants has been the great aim of botanists since Jussieu. To obtain the same true insight into the relations of animals has stimulated the labours of zoologists since the writings of Cuvier. To that great man appertains the merit of having systematically pursued and applied anatomical researches to the discovery of the true system of distribution of the animal kingdom: nor, until the Cuvierian amount of zootomical science had been gained, could the value and importance of Aristotle's 'History of Animals' be appreciated. The Greek philosopher, in this department of science, had advanced far beyond his systematic depreciator, Bacon, who could not, in fact, in the then state of natural knowledge, comprehend his discoveries. Such was the low state of Zoology in the interval between Aristotle and Cuvier, that there is no similar instance, in the history of science, of the well-lit torch gradually growing dimmer and smouldering through so many generations and centuries before it was again fanned into brightness, and a clear view regained, both of the extent of ancient discovery, and of the true course to be pursued by modern research.

Rapid and right has been the progress of Zoology since that resumption.

Not only has the structure of the animal been investigated, even to the minute characteristics of each tissue, but the mode of formation of such constituents of organs, and of the organs themselves, has been pursued from the germ, bud, or egg, onward to the maturity and decay of the individual.

To the observation of outward characters is now added that of inward organization and developmental change, and Zootomy, Histology, and Embryology combine their results in forming an adequate and lasting basis for the higher axioms and generalizations of Zoology properly so called.

Three principles, of the common ground of which we may ultimately obtain a clearer insight, are now recognized to have governed the construction of animals:—unity of plan, vegetative repetition, and fitness for purpose. The last, alone, has of late been questioned: but, in reference to such structures as are exemplified by the flood-gates of the heart and the lens of the eye, I find my own powers of conception and expression such as to leave me no other mode of understanding myself, or of being intelligible to others, than by using the terms 'aim,' 'end,' 'purpose,' or 'design,' in regard to the relation of the first instanced structure to the course of the blood in the circulatory system; and of the second to the convergence of light in the act of vision.

The independent series of researches by which students of the Articulate animals have seen, in the organs performing the functions of jaws and limbs of varied powers, the same or homotypal elements of a series of like segments constituting the entire body, and by which students of the Vertebrate animals have been led to the conclusion that the maxillary, mandibular, hyoid, scapular, costal and pelvic arches, and their appendages sometimes forming limbs of varied powers, are also modified elements of a series of essentially similar vertebral segments,—mutually corroborate their respective conclusions. It is not probable that a principle which is true for *Articulata* should be false for *Vertebrata*: the less probable, since the determination of homologous parts becomes the more possible and sure in the ratio of the perfection of the organization.

The last proposition may be tested by a study of any single set of organs with a view to determine their homologies.

Take, for instance, the teeth, or the organs properly so called, which are peculiar to the vertebrate animals. One cannot trace any particular tooth, as one may a bone, from Fish to Fish: they are too numerous and too uniform. In Reptiles we may point to the maxillary poison-tooth of a Rattlesnake as answering to that in a Cobra; the homological relations of the teeth being only predicable in a general way, as premaxillary, maxillary, mandibular, palatine, in the rest of that class. But when we come to the Mammalia, we find, save in a few inferior groups resembling fishes (e. g. *Cetacea*) or resembling reptiles (*Bruta*), that the teeth have such determinate characters, from relative position and development, as to enable the anatomist to trace each individual tooth from species to species, and indicate it, throughout that large proportion of the class which has been called 'diphyodont,' by a determinate name and symbol.

And here I would repeat, what I have elsewhere expressed, that each year's experience strengthens the conviction that the right and quick progress of the knowledge of animal structures, and of the axioms deducible therefrom, will be mainly influenced by the determination of homologies and by the concomitant power of condensing the propositions relating to homologized parts, by means of definite single substantive names, and their equivalent signs or symbols.

In my work on the 'Archetype of the Skeleton,' I have denoted most of the bones by numerals, which, when adopted, may take the place of names; for then all propositions respecting the centrum of the occipital vertebra might be predicated of '1' as intelligibly as of 'basioccipital.' The name appears to be now generally accepted, and why not the symbol? The symbols of the teeth are as definite as those of the bones; and, in the absence of single names, more useful, since they render unnecessary the repetition of the compound definitions; they harmonize conflicting synonyms, serve as a universal language, and express the writer's meaning in the fewest and clearest terms. The entomologist has realized the advantage of signs, such as ♂, ♀, &c. for male, female, neuter, and the like; and the time is come when the anatomist may avail himself of this powerful instrument of thought, instruction, and discovery, from which the chemist, the astronomer, and the mathematician have obtained such important results.

To William Sharp Macleay, author of the 'Horæ Entomologicæ,' belongs the merit of first clearly defining and exemplifying, in regard to the similarities observable between different animals, the distinction between those that indicate 'affinity' and those that indicate 'analogy' or representation. This distinction has been well illustrated by Vigors in the class of Birds, and has been ably discussed by Swainson in reference to other classes of animals.

'Affinity,' as first defined by Macleay in contradistinction from 'analogy,' signifies the relationship which one animal bears to another in its structure, and is the closer as the similarity of structure is greater. Swainson illustrates this idea by comparing a goatsucker with a swallow and with a bat: with the one its relation is *intimate*, with the other *remote*: the goatsucker has affinity with the swallow, analogy to the bat.

But the idea of the foregoing intimate relation of entire animals, called 'affinity,' is different from the idea of the answerable relation of parts of animals called 'homology.' Animals, however intimately 'affined,' are never the same in the sense in which homologous parts are so esteemed: they could never be called by the same name, in the way or sense in which a bone, for example, of the fore-limb, is called 'humerus' in the goatsucker, swallow, and bat.

There is, indeed, a sameness in the idea of 'analogy,' as applied by the Zoologist to animals, and by the Anatomist to their parts. The goatsucker is related by analogy to a bat, because, as Mr. Swainson remarks, "it flies at the same hour of the day, and feeds in the same manner;" and the membranous wing of the bat is analogous to the membranous parachute of the dragon, because it serves to sustain the body in the air. That is to say, 'function'—a similar relationship to a tertium quid—in the above instance air,—is the groundwork for predicating analogies in regard to parts as well as wholes; more especially when, as in the case of the wings of the dragon and bat, they are not homologous parts.

The study of homologous parts in a single system of organs—the bones—has mainly led to the recognition of the plan or archetype of the highest primary group of animals, the *Vertebrata*. The next step of importance will be to determine the homologous parts of the nervous system, of the muscular system, of the respiratory and vascular system, and of the digestive, secretory, and generative organs in the same primary group or province. I think it of more importance to settle the homologies of the parts of a group of animals constructed on the same general plan, than to speculate on such relations of parts in animals constructed on demonstratively distinct plans of organization. What has been effected and recommended, in regard to homologous parts in the *Vertebrata*, should be followed out in the *Articulata* and *Mollusca*.

In regard to the constituents of the crust or outer skeleton and its appendages in the *Articulata*, homological relations have been studied and determined to a praiseworthy extent, throughout that province.

The same study is making progress in the *Mollusca*; but the grounds for determining special homologies are less sure in this subkingdom. The vegetative functions here predominate; and just as the organs of these functions are less satisfactory subjects of homological determination than those of the animal functions in the Vertebrate province, so the Molluscous province is a less favourable field for homological demonstrations than either the Articulate or Vertebrate provinces, in which the animal functions predominate over the vegetative.

So far as homologies can be determined, within the limits in which such determination can be most satisfactorily carried out, the foundation will be securely laid for a superstructure of higher generalizations in regard to parts homological or answerable throughout the animal kingdom generally.

The present state of homology in regard to the *Articulata* has sufficed to demonstrate that the segment of the crust is not a hollow expanded homologue of the segment of the endoskeleton of a vertebrate. There is as little homology between the parts and appendages of the segments of the Vertebrate and Articulate skeletons respectively. The parts called mandibles, maxillæ, arms, legs, wings, fins, in Insects and Crustaceans, are only 'analogous' to the parts so called in Vertebrates.

To express finitely the clear deideas now possessed of their essential distinction, will require a distinct nomenclature. The same remark is applicable to other systems of organs. The so-called 'lungs' of the spider are analogous to, not homologous with, our 'lungs:' the tracheæ of insects are not homologous with the bird's trachea and its ramifications: the gills of the lobster are not the homologous parts of the gills of fishes. No comparative anatomist now supposes that the heart of the lobster is homologous with that of a fish; or either of these organs with the heart of a snail. The name in each group is simply expressive of similarity of function, and of connexions limited by and solely related to such function, as of the heart with a vein and an artery. A most extensive field of reform is becoming open to the homologist in that which is essential to the exactitude of his science—a nomenclature equivalent to express his convictions of the different relations of similitude. Most difficult and recondite are the questions in face of which the march of homology is now irresistibly conducting the philosophic observer. Such, for instance, as the following:—Are the nervous, muscular, digestive, circulating and generative systems of organs more than functionally similar in any two primary provinces of the animal kingdom? Are the homologies of entire systems to be judged of by their functional and structural connexions, rather than by the plan and course of their formation in the embryo?

In the development of animals the vitellus is observed to have different relations to the embryo. But such difference is not always or absolutely associated with a difference of plan of structure: the Cephalopods show a higher development of the same fundamental plan of structure as that of the Gasteropods, but the vitelline phenomena of their development resemble those of *Vertebrata*, not those of *Gasteropoda*.

Even in the last-named restricted molluscous group there are striking differences in the vitelline relations of the embryo. In most the embryo early encloses the vitelline mass; in some, as in *Limax*, much later: and there is what may be termed a temporary vitelline sac.

The yolk undergoes a complete segmentation in placental Mammals, the embryo of which is formed out of the whole vitelline mass, as it is in the whelk, the oyster and the star-fish. The bird, the crocodile and the cuttle-fish resemble each other in the embryo rising out of the yolk, assimilating only a portion, and leaving the rest as an appendage until the period of birth, or for a short time after.

It may be doubted, therefore, if embryology alone is decisive of the question whether homology can be predicated of the alimentary canal in animals of different primary groups or provinces. The armadillo (*Dasypus*) and the woodlouse (*Oniscus*) are good subjects for illustrating this question. In both, the alimentary canal begins at the fore part and terminates at the hind part of the body: in both, an œsophagus precedes a stomach, as this precedes the part of the canal receiving the biliary secretion; in both, the intestine follows to terminate at the vent.

Besides the sameness of function, the homologist, confiding in the characters of connexion and relative position, would retain the names 'alimentary canal,' 'mouth,' 'gullet,' 'stomach,' 'gut,' to express his ideas of the veritable answerable character of the parts compared in *Oniscus* and *Dasypus*: but he who believes embryology alone capable of affording a solid basis for determining homologies*, will infer that the different relations of the yolk and the intestine in the embryos of the vertebrate and articulate

* "Embryology affords further a test for homologies in contradistinction to analogies. It shows that true homologies are limited respectively within the natural boundaries of the great branches of the animal kingdom."—Agassiz, Nat. Hist. of the United States, 4to, 1857, vol. i. p. 86.

animals*, establish that the so-called alimentary canal is an essentially different part in the mammal and the insect.

The almost annular ossified segments of the skin of the armadillo, arranged so as to overlap and allow the body to be contracted into a ball, are, on the basis of connexions and relative position, homologous with the almost annular chitinous segments of the skin of the wood-louse, which present the same arrangement for permitting that insect to roll itself into a ball. But, according to the embryological basis, there can be no true homology between the parts compared; this relation being limited respectively within the natural boundaries of the great branches of the animal kingdom.

The zoologist may learn from the above instances the phase at which the philosophical study and comparison of animal structures has now arrived, and I shall not pursue the disquisition further on the present occasion.

It is significant, however, of the lower value of embryological characters, to note that the great leading divisions of the animal kingdom, based by Cuvier on comparative anatomy, have merely been confirmed by Von Baer's later developmental researches. And so, likewise, with regard to some of the minor modifications of Cuvier's provinces, the true position of the *Cirripedia* was discerned by Straus Durkheim and Macleay, by the light of anatomy, before the discovery of their metamorphoses by Thomson.

If, however, embryology has been over-valued as a test of homology, the study of the development of animals has brought to light most singular and interesting facts, and I now allude more especially to those that have been summed up under the term 'Alternate-generation,' 'Parthenogenesis,' 'Metagenesis,' &c.

John Hunter first enunciated the general proposition (many of the facts being known long before his time), that "the propagation of plants depended on two principles, the one that every part of a vegetable is 'a whole,' so that it is capable of being multiplied as far as it can be divided into distinct parts; the other, that certain of those parts become reproductive organs, and produce fertile seeds." Hunter also remarked that "the first principle operated in many animals which propagate their species by buds or cuttings;" but that, whilst in animals, it prevailed only in "the more imperfect orders," it operated in vegetables "of every degree of perfection." He suggestively remarks, however, that "those degrees are few in comparison with the 'animal,' and that the least perfect 'animal' is probably on a par with the most perfect 'vegetable†.'" Subsequent progress has shown that what seemed 'probable' when Hunter wrote is not exactly true. The special conditions of organisms or living things, which we call 'vegetable' and 'animal,' rise by degrees and diverge from a general organic character or

* "The alimentary canal is formed in a very different way in the embryos of the two types; and it would be as unnatural to identify them, as it would be still to consider gills and lungs as homologous among Vertebrata."—Agassiz, *op. cit.*, p. 86.

† Physiol. Catal., p. 5.

basis: and the degree of progress at which 'animality' can be predicated, is 'on a par' with that at which 'vegetality' can be predicated. Then follow other steps of complexity, by which plants and animals diverge from each other as they rise in the scale of perfection.

The experiments of Trembley on the freshwater polype, those of Spallanzani on the Naiads, and those of Bonnet on the Aphides, had brought to light the phenomena of propagation by fission, and by gemmation or buds, external and internal, in animals, to which Hunter refers. Subsequent research has shown the unexpected extent to which Hunter's first principle of propagation in organic beings prevails in the animal division. But the earliest formal supersession of Harvey's axiom, 'omne vivum ab ovo,' appears to be Hunter's proposition of the dual principle above quoted. Bacon readily accepted, as, indeed, it was congenial with his physiological philosophy, the doctrine current in his day of the spontaneous origin of worms, insects, eels, and other 'creeping things.' But this doctrine receives no countenance from the modification of the Harveian dictum introduced by the great English physiologist of the last century.

The experiments of Redi, Malpighi, and others, had progressively contracted the field to which the 'generatio æquivoca' could with any plausibility be applied. The stronghold of the remaining advocates of that old Egyptian doctrine was the fact of the development of parasitic animals in the flesh, brain and glands of higher animals. But the hypothesis never obtained currency in this country; it was publicly opposed in my 'Hunterian Lectures,' by the fact of the prodigious preparation of fertile eggs in many of the supposed spontaneously developed species; and in then suggesting that the '*Trichina spiralis*' of the human muscular tissue might be the embryo of a larger worm in course of migration, I urged that a particular investigation was needed for each particular species*. Among the most brilliant of recent acquisitions to this part of physiology have been the discoveries which have resulted from such special investigations. Kuchenmeister and Von Siebold have been the chief labourers in this field. I may instance a few of their results.

The 'thread-worms' (*Filariæ*) of certain insects, which present no trace of sexual organs, were supposed to be spontaneously developed in those insects. The little worms were, however, by special and due research, seen to wind their way out of the caterpillars they infested. Von Siebold placed these free *Filariæ* in damp earth, into which they soon bored: in a few weeks he found that the sexual organs were developed in them, and that they laid hundreds of eggs. Early in spring the young worms were hatched and began to creep about. Von Siebold took some young caterpillars of the moth (*Yponomeuta euonymella*), in which were no parasites: he placed them in the soft earth in which the young *Filariæ* had been hatched; and in twenty-four hours most of the caterpillars were infested by the young

* Hunterian Lectures, reported in 'Medical Times.'

thread-worms, which had bored their way through the soft skin into their interior.

The long hair-worm of fresh-waters (*Gordius aquaticus*), vulgarly conceived to be the result of a metamorphosis of the hair of a horse's tail, passes its early life as a parasite in the body of an insect.

But many entozoa acquire their full or sexual development, not as free worms, but within the body of another animal, and of a species distinct from that in which they had passed the early or larval stage of their existence.

The trematode parasite of a water-fowl produces eggs, from each of which is hatched a ciliated infusorial-like young. These young escape into the water, and there swim about by their vibratile cilia, like *Infusoria*; some of them enter the body of a water-snail; but they are merely the locomotive envelope of a differently-shaped smooth-skinned organism, resembling in its simple uniform granular structure a *Gregarina*; and the function of that ciliated envelope was to introduce the *Gregarina* into the body of the water-snail. So introduced, the growth of the gregariniform parasite proceeds, and a progeny is seen to arise in its interior, by the development of several of the contained germ-cells into embryos: it proves, indeed, to be a mere cyst for such, as the infusorial larva had been a cyst for it. The embryos gradually acquire the form of a *Cercaria*. These escape from the cyst, bore their way out of the snail, and disperse themselves as free swimming tadpole-like animalcules in the water. No sexual organs exist in these '*Cercariæ*,' any more than in their animated 'coat' the *Gregarina*, or in their ciliated 'great-coat' the infusorial embryo. After the larval *Cercariæ* have passed some time in the water, first creeping and then swimming about with great restlessness, they either enter directly the body of a water-fowl, or bore their way into some aquatic insect, or they may fail in both these instinctive efforts and remain in the water. In any case they undergo a metamorphosis. The *Cercaria* gathers itself up into a ball and exudes a mucous secretion from its surface, which soon hardens; and, since the worm, inside this mucous mass, turns round without stopping, it invests itself with a kind of egg-shell: during this process the tail is cast off.

Should this process take place within the body of an insect, the encysted *Cercaria* might be introduced into the body of an insectivorous bird or beast. In the act of digestion by the engulpher the body of the insect is destroyed, together with the capsule of the cercarian pupa; but this by virtue of its vitality remains unharmed, and is thus transplanted into a sphere fitted for its further change into a sexual entozoon of the Trematode or 'fluke-worm' order.

Then again commences the strange and complex genetic cycle from the Harveian point—the impregnated ovum.

Three different species of animal may contribute—two are essential—to the successful progress of the ordinary and parthenogenetic processes of propagation manifested by the three distinct forms of Infusory, Gregarina and Cercaria, intervening between the egg and the perfect parasitic fluke-worm.

This instance (a knowledge of which is due chiefly to the researches of Von Siebold) I have thought it requisite to quote, in order to convey some idea to my non-physiological auditors of the singular complexity of powers and arrangements tending to the ultimate right lodgement and well-being of a seemingly insignificant noxious little parasite.

The sum of the recent researches on the generation of the Entozoa teaches that to the success in life of the majority of these internal parasites, two different species of much higher organized animals are subservient; and that these two species stand in the relation of prey and devourer.

The habits of the prey favour the accidental introduction (as when a slug crawls over the droppings of a thrush) of the eggs of the birds' intestinal parasite. These are hatched in the slug. The slug in its turn is devoured by the thrush; but the parasitic passengers are not digested—only the coach is dissolved, and the larvæ, thus set free, find in the warm intestines of the bird the appropriate conditions for their metamorphosis and full development.

In like manner, the *Rhynchobothria* of a cuttle-fish are the larvæ of the *Tetrarhynchus* or four-tentacled tape-worm of a dog-fish. The encysted sexless *Triænophorus* of the liver of the char becomes the free and perfect *Triænophorus* of the gut of the pike. The *Ligula* of a herring becomes a *Tænia* only when introduced into the interior of a cormorant. The bladder-worm (*Cysticercus fasciolaris*) of the mouse's liver becomes the tape-worm (*Tænia crassicollis*) of the cat. The *Cysticercus pisiformis* of the liver of the hare becomes the *Tænia serrata* of the dog and fox.

Dr. Küchenmeister of Zittau first proved, experimentally, by feeding animals with *Cysticerci* (Hydatids of the flesh and glands of herbivorous animals), that they became *Tæniæ* (intestinal tape-worms) in carnivorous animals. The results of these instructive experiments were published in 1851 *. They have been successfully repeated, amplified, and scientifically explained, in regard to every particular and step of the progress, by the indefatigable and accurate Von Siebold †. The part which *Parthenogenesis* plays in the changing scenes of entozoal life is acutely discerned and clearly explained in this work.

Since the time when it was first discovered that plants and animals could propagate in two ways, and that the individual developed from the bud might produce a seed or egg, from which also an individual might spring capable of again budding,—since this alternating mode of generation was observed, as by Chamisso and Sars, in cases where the budding individual differed much in form from the egg-laying one—the subject has been systematized ‡, generalized, with an attempt to explain its

* Gunsburg's Zeitschrift für Klinische Vorträge, 1851, p. 240.

† Ueber die Band- und Blasenwürmer, &c. 8vo. Leipzig, 1854.

‡ Steenstrup (J.), "Ueber den Generationswechsel oder die Fortpflanzung durch abwechselnde Generation," Kopenh. 1842. 8vo.

principle*, and greatly advanced†, especially, and in a highly interesting manner, in Von Siebold's late treatise, entitled "Wahre Parthenogenesis bei Schmetterlingen und Bienen," in which the virgin-production of the male or drone-bee is demonstrated.

Von Siebold, having subjected to the closest microscopic scrutiny and experiment the conclusion to which the practical Bee-master Dzierson had arrived, relative to the cause of Queen-bees with crippled wings producing a swarm exclusively of drones, has demonstrated that the male-bee is produced from an egg which has been subjected to no influence save that of the maternal parent; whilst such egg, if impregnated, would have produced a female or worker-bee.

Von Siebold has established the same most interesting phase of parthenogenesis in certain *Lepidoptera*, e. g. *Solenobia lichenella*, *S. clathrella*, *Psyche helix*; and he calls this phase emphatically 'true parthenogenesis.'

Bonnet's famous experiments on the parthenogenetic Aphides have been repeated and confirmed by myself‡ and others. Hartig§ has shown the same property in the genera *Cynips* and *Apophyllus*, which explains the fact of the appearance of *Cynips lignicola* in vast numbers in the south-west of England during the present and preceding summers, but all of the female sex. The little crustaceans of the genus *Daphne* have long been known to produce agamic eggs. A newly-hatched female isolated in a tumbler will produce a brood of the same sex, whence a second brood will issue, to perhaps the sixth generation. Mr. John Lubbock, in an admirable paper in the 'Philosophical Transactions' for 1857, has repeated the experiments of Jurine, and added many valuable facts. He has pointed out the precise relations between the agamic and ephippial eggs. The young from any one brood of agamic eggs are all of one sex, which usually is female: but in one instance Mr. Lubbock observed that they were all males. His memoir will well repay a careful study. I had previously stated the grounds for concluding that there was no essential distinction between buds and eggs, and for anticipating that every gradation would be found between them: and many steps in that series have been since supplied by Lubbock, Leidy, and Von Siebold.

Gærtner has given an abridged account of experiments, showing that

* OWEN, "On Parthenogenesis, or the Successive Production of Procreating Individuals from a single Ovum," 8vo. London, 1849.

Ib. "On Metamorphosis and Metagenesis," 8vo. 1857.

Prosch (V), "Om Parthenogenesis og Generationsvexel," Kiöbenhavn, 1851.

† Lubbock (J.), "An Account of Two Methods of Reproduction in Daphnia," &c., Phil. Trans. 1857, p. 79.

Carus (J. Victor), "Zur näheren Kenntniss des Generationswechsels," 8vo. Leipzig, 1849.

Leuckart (K.), "Ueber Metamorphose ungeschlechtliche Vermehrung, Generationswechsel," Zeitschrift für Wissensch. Zoologie, vol. iii. 1851.

Gegenbaur (U.), "Zur Lehre vom Generationswechsel und der Fortpflanzung bei Medusen und Polypen," 8vo. Würzburg, 1854.

‡ Parthenogenesis.

§ Germar's Zeitschrift, vol. ii. p. 178.

some plants have the power of producing 'agamic' or fertile but unpollenized seeds: e.g. *Zea Mays*, *Cannabis sativa*, *Spinacia oleracea*, *Mercurialis annua*; and if doubt may yet attend the results of the experiments on these and other plants which Gærtner cites, none, I believe, is now entertained by botanists of the germinative power of the seeds, independently of any action of pollen, of the *Cœlobogyne ilicifolia*. This plant, a native of Moreton Bay, Australia, is diœcious like the rest of the order (*Euphorbiaceæ*) to which it belongs. A female plant was sent to the Royal Botanic Gardens at Kew some years ago, where it may now be seen in full vigour; but year after year this pistil-bearing individual has formed its flowers and fertile seeds as perfectly reproductive as if its staminiferous mate was blooming in the next parterre. No male plant has yet, in fact, been introduced.

M. Lehocq has recorded in the 'Comptes Rendus de l'Acad. des Sciences,' Dec. 1856, the same phenomena in *Trinia vulgaris*, *Mercurialis annua*, and some other plants.

The now well-investigated phenomena of parthenogenesis in *Hydrozoa* have resulted in showing, as in the analogous case of *Entozoa*, that animals differing so much in form as to have constituted two distinct orders or classes, are really but two terms of a cycle of metagenetic transformations—the acalephan *Medusa* being the sexual locomotive form of the agamic rooted budding polype, just as the cestoid Tænia is of the cystic Hydatid.

In *Hydrozoa* (Hydroid Polypes or Sertularians) the young are propagated, as in plants, by 'buds, and also, as in most plants, by 'germs' or 'seeds:' these latter are contained in 'germ-sacs' projecting from the outer surface, which is another analogy to the flowering parts of plants. The germ-sac contains either bare-eyed medusæ, or medusoid germs in small closed 'sporosacs.' Both medusæ and medusoids contain either the eggs or the pollen-like zoosperms. The germ-sac may be 'simple' or 'compound,' the latter containing a special organ or process of the 'cænosarc,' from whose sides bud out the sporosacs or medusæ.

The first acquaintance with these marvels excited the hope that we were about to penetrate the mystery of the origin of different species of animals; but as far as observation has yet extended, the cycle of changes is definitely closed. And, since one essential step in the series is the fertilized seed or egg, the Harveian axiom, 'omne vivum ab ovo,' if metagenetic phases be ascribed to one individual, may be still predicated of all organisms which bear the unmistakeable characters of Plants or of Animals.

The closest observations of the subjects of these two kingdoms most favourable to clear insight into the nature of their beginning, accumulate evidence in proof of the essential first step being due to the protoplasmic matter of a germ-cell and sperm-cell; the former pre-existing in the form of a nucleus or protoplast, the latter as a granulose fluid. In flowering plants it is conveyed by the pollen-tube, in animals and many flowerless plants by locomotive spermatozoids.

In regard to lower living things, analogy is but hazardous ground for conclusions. The single-celled organisms, such as many of the so-called animalcules of infusions, which are at a stage of organization too low for a definite transfer to either the vegetable or animal kingdoms, offer a field of observation and experiment which may yet issue in giving us a clearer insight into the development of the organic living cell.

Whether an independent free-moving and assimilating organism, of a grade of structure similar to, and scarcely higher than the 'germ-cell,' may not arise by a collocation of particles, through the operation of a force analogous to that which originally formed the germ-cell in the ovarian stroma, is a question which cannot be answered until every possible care and pains have been applied to its solution.

The changes of form which the representative of a species undergoes in successive agamically propagating individuals are termed the 'metagenesis' of such species. The changes of form which the representative of a species undergoes in a single individual is called the 'metamorphosis.' But this term has practically been restricted to the instances in which the individual, during certain phases of the change, is free and active, as in the grub of the chaffer, or the tadpole of the frog, for example.

In reference to some supposed essential differences in the metamorphoses of insects, it had been suggested that stages answering to those represented by the apodal and acephalous maggot of the *Diptera*, by the hexapod larva of the *Carabi*, and by the hexapod antenniferous larvæ of the *Meloe* were really passed through by the orthopterous insect, before it quitted the egg*.

Mr. Andrew Murray† has recently made known some facts in confirmation of this view. He had received a wooden idol from Africa, behind the ears of which a Blatta had fixed its egg-cases, after which the whole figure had been rudely painted by the natives, and these egg-cases were covered by the paint. No insect could have emerged without breaking through the case and the paint; but both were uninjured. In the egg-cases were discovered,—1st, a grub-like larva in the egg; 2nd, a cocoon in the egg containing the unwinged, imperfectly-developed insect; 3rd, the unwinged, imperfectly-developed insect in the egg, free from the cocoon, and ready to emerge.

Such observations tending to remove supposed exceptions and anomalies, and to illustrate and establish the common law to which they can be reduced, are of the highest value in Natural History.

Microscope.—The microscope is an indispensable instrument in embryological and histological researches, as also in reference to that vast swarm of animalcules which are too minute for ordinary vision. I can here do little more than allude to the systematic direction now given to the application of

* Owen, "On Metamorphosis and Metagenesis," 1851, and "Lectures on Invertebrata," 8vo, 1855, p. 424.

† "On the Metamorphosis of Orthopterous and Hemipterous Insects," Edinb. Phil. Journal, 1858.

the microscope to particular tissues and particular classes, chiefly due, in this country, to the counsels and example of the Microscopical Society of London.

A very interesting application of the microscope has been made to the particles of matter suspended in the atmosphere; and a systematic continuation of such observations by means of glass slides prepared to catch and retain atmospheric atoms, promises to be productive of important results.

We now know that the so-called red-snow of Arctic and Alpine regions is a microscopic single-celled organism which vegetates on the surface of snow.

Cloudy or misty extents of dust-like matter pervading the atmosphere, such as have attracted the attention of travellers in the vast coniferous forests of North America, and have been borne out to sea, have been found to consist of the 'pollen' or fertilizing particles of plants, and have been called 'pollen showers.'

M. Daneste*, submitting to microscopic examination similar dust which fell from a cloud at Shanghai, found that it consisted of spores of a confervoid plant, probably the *Trichodesmium erythræum*, which vegetates in, and imparts its peculiar colour to, the Chinese Sea.

Decks of ships, near the Cape de Verd Islands, have been covered by such so-called 'showers' of impalpable dust, which, by the microscope of Ehrenberg, has been shown to consist of minute organisms, chiefly 'Diatomaceæ.' One sample collected on a ship's deck 500 miles off the coast of Africa, exhibited numerous species of freshwater and marine diatoms bearing a close resemblance to South American forms of those organisms. Ehrenberg has recorded numerous other instances in his paper printed in the 'Berlin Transactions;' but here, as in other exemplary series of observations of the indefatigable microscopist, the conclusions are perhaps not so satisfactory as the well-observed data.

He speculates upon the self-developing power of organisms in the atmosphere, affirms that dust-showers are not to be traced to mineral material from the earth's surface, nor to revolving masses of dust material in space, nor to atmospheric currents simply; but to some general law connected with the atmosphere of our planet, according to which there is a 'self-development' within it of living organisms, which organisms he suspects may have some relation to the periodical meteorolites or aërolites. The advocates of progressive development may see and hail in this the first step in the series of ascending transmutations. The unbiassed observer will be stimulated by the startling hypothesis of the celebrated Berlin Professor to more frequent and regular examinations of atmospheric organisms. Some late examinations of dust-showers clearly show them to have a source which Ehrenberg has denied. Some of my hearers may remember the graphic description by Her Majesty's Envoy to Persia, the Hon. C. A. Murray, of the cloud of impalpable red dust which darkened the air of Bagdad, and filled the city

* Annales des Sciences Naturelles, sér. 4. Botanique, t. i. p. 81.

with a panic. The specimen he collected was examined by my successor at the Royal College of Surgeons, Prof. Quekett; and that experienced microscopist could detect only inorganic particles, such as fine quartz sand, without any trace of Diatomaceæ or other organic matter. Dr. Lawson has obtained a similar result from the examination of the material of a shower of moist dust or mud which fell at Corfu in March 1857: it consisted for the most part of minute angular particles of a quartzose sand.

Here, therefore, is a field of observation for the microscopist, which has doubtless most interesting results as the reward of persevering research.

Many 'dust-showers' consist in greater or less proportions of microscopic organisms, but not all. To determine the source of these organisms is the legitimate aim of such researches. It must be remembered, also, that the expression 'spontaneously developed' in the atmosphere, may only mean what is meant when it was formerly applied to the internal parasites of man and animals, viz. ignorance of the true mode of origin. And since persevering observation and experiment, in regard to tape-worms and ascarides, have thrown such new and unexpected light upon their origin and migrations, so the like result may reward similar labours applied to the parasitic 'dust-showers' of the atmosphere.

Microgeology.—The microscopic organisms hitherto observed in the oldest fossiliferous deposits, Silurian Greensands, for instance, are spicula of *Spongiæ*, siliceous *Polycystineæ*, and calcareous *Foraminifera*.

Ehrenberg has discovered that the substance of the greensands in stratified deposits, from the Silurian to the Tertiary periods inclusive, is composed of the casts of the interior of the microscopic shells of *Polycystineæ* and *Foraminifera*. The soundings which have been brought up from various parts of the Atlantic and the Gulf of Mexico, consist chiefly of similar microscopic polythalamous shells, mingled with a greensand composed of casts of *Foraminifera*. Thus the mode in which a deposit was made at the bottom of the deep primeval ocean of the Silurian period, is illustrated by that which the microscope has demonstrated to take place under similar conditions at the present day.

The earliest indubitable evidence of diatoms has been obtained from the Eocene strata; and the forms here determined have been for the most part identified with existing species. Exotic species are not distinguishable from the British; difference of climate seems not to affect or relate to specific difference, and the same exemption from such influence through the minute size and simple structure of the Diatomaceæ, seems to have been the chief condition of their geological longevity as species.

To specify or analyse the labours of the individuals who of late years have contributed to advance zoology by the comprehensive combination of the various kinds of research now felt to be essential to its right progress, would demand a proportion of the present discourse far beyond its proper and allotted limits.

Yet I shall not be deemed invidious if I cite one work as eminently exemplary of the spirit and scope of the investigations needed for the elucidation of any branch of Natural History. That work is the monograph of the Chelonian Reptiles (Tortoises, Terrapenes and Turtles) of the United States of America, published last year at Boston, U.S., by Professor Agassiz.

I cite it, not wholly on account of its intrinsic merits, but also because it affords me the opportunity of expressing, on the part of naturalists, the admiration of, and deep sense of gratitude to, the great and liberal people whose perception of the intrinsic value and dignity of pure science has enabled the distinguished author to enrich zoology by a work unparalleled in the completeness, perfection, and consequent expense of its graphic illustrations.

"We had fixed," writes Agassiz, "upon five hundred subscribers as the number necessary to enter upon the publication with safety:—at this moment it stands at twenty-five hundred,—a support such as was never before offered to any scientific man for purely scientific ends, without any reference to government objects or direct practical aims*."

Geographical Distribution of Plants.—Observations of the characters of plants, the record of such observations by the Linnæan and subsequently improved artifices of description, the application of this power to comparison, and deductions from the results of such comparisons,—have led to the recognition of the natural groups or families of the vegetable kingdom, and to a clear scientific comprehension of that great department of living Nature.

This phase of botanical science gives the power of further and more profitable generalizations, such as those teaching the relations between the particular plants and particular localities.

The sum of these relations, forming the Geographical Distribution of Plants, rests, perhaps at present necessarily, on an assumption, viz. that each species has been created, or come into being, but once in time and space; and that its present diffusion is the result of its own law of reproduction, under the diffusive or restrictive influence of external circumstances. These circumstances are chiefly temperature and moisture, dependent on the distance from the source of heat and the obliquity of the sun's rays, modified by altitude above the sea-level, or the degree of rarefaction of the atmosphere, and of the power of the surface to radiate heat. Both latitude and altitude are further modified by currents of air and ocean, which influence the distribution of the heat they have absorbed. Thus large tracts of dry land produce dry and extreme climates, while large expanses of sea produce humid and equable climates. Botany, in short, at this phase becomes intimately related to climatology; and the traveller, the meteorologist, and the naturalist reciprocally aid each other in the acquisition of a knowledge of fruitful general laws. Agriculture affects the geographical distribution of plants, both directly and indirectly. It diffuses plants over a wider area of

* Agassiz, "Monograph on North American Testudinata," 4to, Boston, 1857, Preface, p. viii. vol. i. Of the 2500 Subscribers only 20 are Extra-american.

equal climate, augments their productiveness, and enlarges the limits of their capacity to support different climatal conditions. Agriculture also effects local modifications of climate. The clearance of forests, by diminishing the cooling influence of evaporation from leaves, increases the temperature. When, by the spread of thorough drainage over Britain, the surface-water is at once carried off, instead of remaining on the surface until slowly dispersed by evaporation and atmospheric currents, such prompt removal of the raw material of mist and cloud may be reasonably expected to be attended with a greater average annual amount of solar light and heat.

Certain species of plants require more special physical conditions for health; others more general conditions; and their extent of diffusion varies accordingly. Thus the plants of temperate climates are more widely diffused over the surface of the globe, because they are suited to elevated tracts in tropical latitudes.

There is, however, another law which relates to the original appearance, or creation, of plants, and which has produced different species flourishing under similar physical conditions, in different regions of the globe. Thus the plants of the mountains of South America are of distinct species, and for the most part of distinct genera, from those of Asia. The plants of the temperate latitudes of North America are of distinct species, and some of distinct genera, from those of Europe. The *Cacteæ* of the hot regions of Mexico are represented by the *Euphorbiaceæ* in parts of Africa having a similar climate.

The modes of generalizing the observations on the geographical distribution of indigenous plants are various.

One is by dividing the horizontal range of vegetation into zones, bounded by annual isothermal lines, as, 1, the equatorial; 2, tropical; 3, subtropical; 4, warmer temperate; 5, cooler temperate; 6, subarctic; 7, arctic; 8, polar zones: with temperatures progressively falling from an annual isotherm of 79°·3 Fahr. to one of 36°·5 for the month of July.

Another mode is the classification of plants according to the regions of altitude; as into those of,—1, Palms; 2, Tree-ferns; 3, Myrtles; 4, Evergreens; 5, Deciduous trees; 6, Conifers; 7, Alpine shrubs; 8, Alpine herbs. But the corresponding altitudes in different countries have frequently different, though analogous or representative, species. The presence or otherwise of snow on the mountain-tops also influences the character of the plants at corresponding altitudes. Thus, forests of tall Conifers flourish in the Himalayas at regions of altitude where only stunted specimens of tropical plants are found in the mountains of Sumatra.

A third, and perhaps more truly natural mode of expressing the geographical distribution of plants, is by regions defined by the proportion of plant-species peculiar to them. When one half, at least, of the known species are peculiar to a certain space, it constitutes a 'phytogeographic' region, according to Schouw. In it, also, a fourth part of the genera must be either peculiar, or so predominating as to be comparatively rare in other regions; and the individual families of plants must be either peculiar to, or decidedly predominate in, such region.

So defined, the surface of the earth has been divided into twenty-five regions, of which I may cite as examples that of New Zealand, in which Ferns predominate, together with generic forms, half of which are European, and the rest approximating to Australian, South African, and Antarctic forms; and that of Australia, characterized by its *Eucalypti* and *Epacrides*, chiefly known to us by the researches of the great botanist, Robert Brown, the founder of the 'Geography of Plants.'

Of the heaths, or heath-like shrubs, some genera, *Erica*, or true heath, for example, characterize the Cape of Good Hope and Europe; other genera the Cape and New Holland; others again, as *Epacris*, *Lissanthe*, and *Leucopogon*, are characteristic of Australia.

The vegetable kingdom has been classified into many such physiognomical groups. The latest botanical statistics make 213,280 species; but the best informed botanists believe that we are still acquainted only with a small proportion of existing plants.

Geographical Distribution of Animals.—Organic Life, in its animal form, is much more developed, and more variously, in the sea, than in its vegetable form.

Observations of marine animals and their localities have led to attempts at generalizing the results; and the modes of enunciating these generalizations or laws of geographical distribution are very analogous to those which have been applied to the vegetable kingdom, which is as diversely developed on land as is the animal kingdom in the sea. Certain horizontal areas, or provinces, have been characterized by the entire assemblage of animals and plants constituting their population, of which a considerable proportion is peculiar to each province, and the majority of the species have their areas of maximum development within it.

Of such provinces of Marine Life, that much-lamented, far-seeing, and genial philosopher, Edward Forbes, has provisionally defined 25.

The same physical conditions are associated with a certain similarity between the animals of different provinces. Where those provinces are proximate, such likeness is due to the identity or close affinity of the species; but where the provinces are remote, the resemblance is one of analogy, and species of different genera or families represent each other.

A second mode of expressing the ascertained facts of the geographical distribution of marine animals is by tracts called 'Homoiozoic Belts,' bounded by climatal lines, which are not, however, parallel with lines of latitude, but undulate in subordination to climatal influences of warm or cold oceanic currents, relations of land to water, &c. Of these belts, Professor E. Forbes has defined nine: one equatorial, with four to the north and four to the south, which are mutually representative.

But the most interesting form of expression of the distribution of marine life is that which parallels the perpendicular distribution of plants. Edward Forbes, availing himself of the valuable results of a systematic use of the dredge, first showed that marine animals and plants varied according to the depth at which they lived, in a manner very analogous to the changes in the forms and species of vegetation observed in the ascent of a tropical mountain. He has expressed these facts by defining five bathymetrical zones, or belts of depth, which he calls,—1, Littoral; 2, Circumlittoral; 3, Median; 4, Infra-median; 5, Abyssal.

The life-forms of these zones vary, of course, according to the nature of the sea-bottom; and are modified by those primitive or creative laws that have caused representative species in distant localities under like physical conditions,—species related by analogy.

Very much remains to be observed and studied by Naturalists in different parts of the globe, under the guidance of the generalizations thus sketched out, to the completion of a perfect theory. But in the progress to this, the results cannot fail to be practically most valuable. A shell or a sea-weed, whose relations to depth are thus understood, may afford important information or warning to the navigator. To the geologist the distribution of marine life according to the zones of depth has given the clue to the determination of the depth of the seas in which certain formations have been deposited.

By the light of these laws of geographical distribution we view with quite a new interest the shells, corals, and sea-weeds of our own shores. We trace the regions whence they have been invaded by races not aboriginally belonging to our seas; we obtain indications of irruptions of sea-currents of dates anterior to the present arrangements of land and water. Thus, part of our marine fauna has been traced back to the older pliocene period, part to the somewhat newer period of the red-crag, part to the still more recent glacial period—all these being anterior to the constitution of the 'Celtic Province,' as it is now displayed.

With regard to the class of Fishes, some families, the Sharks (Squaloids), Herrings (Halecoids), and Mackerel-kind (Scomberoids), are cosmopolitan. The Labyrinthodonts are limited to the Indian Ocean; the Goniodonts to the rivers of South America; the *Lepidostei* to those of North America; the *Polypteri* to those of Africa. The fish called *Chaca* is restricted to the Lake Baikal, and the blind '*Amblyopsis*' to the Mammoth cave: just as the Proteus amongst amphibious reptiles is confined to the caverns of Carinthia.

The class of animals to which the restrictive laws of geographical distribution might seem least applicable is that of Birds: their peculiar powers of locomotion, associated in numerous species with migratory habits, might seem to render them independent of every influence save those of climate and of food, which directly affect the conditions of their existence. Yet the long-winged Albatros is never met with north of the equator; nor does the Condor soar above other mountains than the Andes. The geographical range of its European representative, the strong-winged Lammer-geyer, is similarly restricted. The Asiatic *Phasianidæ* and *Pavonidæ* are represented by Turkeys (*Meleagris*) in America; by the Guinea-fowl (*Numida, Agelastus, Phasidus*) in Africa; and by the *Megapodidæ*, or Mound-birds, in Australia. Several genera of Finches are peculiar to the Galapagos Islands; the richly and fantastically ornate Birds of Paradise are restricted to New Guinea and some neighbouring isles. Mr. Sclater, who has contributed the latest summary of facts on the distribution of Birds, reckons 17 families as peculiar to America, and 16 families as peculiar to Europe, Asia, and Africa. Some species have a singularly restricted locality, as, the Red-grouse (*Tetrao scoticus*) to the British Isles; the Owl-parrot (*Nestor productus*) to Philip Island, a small spot near New Zealand.

When birds have wings too short for flight, we marvel less at their restricted range; and particular genera of brevipennate birds have their peculiar continents or islands. The long- and strong-limbed Ostrich courses over the whole continent of Africa and conterminous Arabia. The genus of three-toed Ostriches (*Rhea*) is similarly restricted to South America. The Emeu (*Dromaius*) has Australia assigned to it. The continent of the Cassowary (*Casuarius*) has been broken up into islands including and extending from the south-eastern peninsula of Asia to New Guinea and New Britain. The singular nocturnal wingless Kivi (*Apteryx*) is peculiar to the islands of New Zealand.

Other species and genera, which seem to be, like the *Apteryx*, as it were mocked with feathers and rudiments of wings, have wholly ceased to exist within the memory of man in the islands to which they also were respectively restricted. The Dodo (*Didus ineptus*) of the Mauritius, and the Solitaire (*Pezophaps solitaria*) are instances.

In New Zealand also there existed, within the memory of the Maori ancestry, huge birds having their nearest affinities to the still existing *Apteryx* of that island, but generically distinct from that and all other known birds. I have proposed the name of *Dinornis* for this now extinct genus, of which more than a dozen well-defined species have come to my knowledge, all peculiar to New Zealand and the last-discovered the strangest, by reason of the elephantine proportions of its feet.

A tridactyle wingless bird of another genus, *Æpyornis*, second only to the gigantic *Dinornis* in size, appears to have also recently become extinct—if it be extinct—in the Island of Madagascar. The egg of this bird, which may have suggested to the Arabian voyagers attaining Madagascar from the Red Sea the idea of the Roc of their romances, would hold the contents of 6 eggs of the Ostrich, 16 eggs of the Cassowary, and 148 eggs of the common Fowl.

The laws of geographical distribution, as affecting mammalian life, have been reduced to great exactness by observations continued since the time of Buffon, who first began to generalize, just a century ago, in that way, noting the peculiarities of the species of South American animals *. The most important extension of this branch of zoology has been due to recent researches and discoveries of extinct species of the class Mammalia; and it is chiefly in relation to the modifications of zoological ideas produced by palæontology that a few brief remarks will here be made.

The Quadrumana, or order of Apes, Monkeys, and Lemurs, consist of three chief divisions—Catarhines, Platyrhines, and Strepsirhines. The first family is peculiar to the 'Old World;' the second to South America; the third has the majority of its species, and its chief genus (*Lemur*), exclusively in Madagascar. Out of 26 known species of *Lemuridæ*, only 6 are Asiatic and 3 are African.

The Catarhine monkeys include the Macaques, most of which are Asiatic, a few are African, and one European; the Cercopitheques, most of which are African, and a few Asiatic; and other genera which characterize one or other continent exclusively. Thus the true Baboons (*Papio*) are African, as are the thumbless Monkeys (*Colobus*) and the Chimpanzees (*Troglodytes*). The Semnopitheques, Gibbons, and Orangs are peculiarly Asiatic. Palæontology has shown that a Macaque, a Gibbon, and an Orang existed during the older tertiary times in Europe; and that a Semnopithecus existed in miocene times in India. But all the fossil remains of Quadrumana in the Old World belong to the family *Catarhina*, which is still exclusively confined to that great division of dry land. The tail-less Macaque (*Inuus silvanus*) of Gibraltar may have existed in that part of the Old World before Europe was separated by the Straits of Gibraltar from Africa. Fossil remains of Quadrumana have been discovered in South America; they indicate Platyrhine forms: a species, for example, allied to the Howlers (*Mycetes*), but larger than any now known to exist, has left its remains in Brazil.

Whilst adverting to the geographical distribution of Quadrumana, I would contrast the peculiarly limited range of the Orangs and Chimpanzees with the cosmopolitan powers of mankind. The two species of Orang (*Pithecus*) are confined to Borneo and Sumatra; the two species of Chimpanzee (*Troglodytes*) are limited to an intertropical tract of the western part of Africa. They appear to be inexorably bound by climatal influences regulating the assemblage of certain trees and the production of certain fruits. With all our care, in regard to choice of food, clothing, and contrivances for artificially maintaining the chief physical conditions of their existence, the healthiest specimens of Orang or Chimpanzee, brought over in the vigour of youth, perish within a period never exceeding three years, and usually much shorter, in our climate. By what metamorphoses, we may ask, has the

* The first enunciation of the principle of Geographical Distribution merits reproduction. Buffon was treating of the carnivorous animal which travellers in South America had called the 'Lion':—"Le *puma* n'est point un lion, tirant son origine des lions de l'ancien continent; c'est un animal particulier à l'Amérique, comme le sont aussi la plupart des animaux de ce nouveau continent."—Tom. ix. p. 13, 1758.

alleged humanized Chimpanzee or Orang been brought to endure all climates? The advocates of 'transmutation' have failed to explain them. Certain it is that those physical differences in cerebral, dental, and osteological structure, which place, in my estimate of them, the genus *Homo* in a distinct group of the mammalian class, zoologically of higher value than the 'order,' are associated with equally contrasted powers of endurance of different climates, whereby Man has become a denizen of every part of the globe from the torrid to the arctic zones.

Climate rigidly limits the range of the Quadrumana latitudinally: creational and geographical causes limit their range in longitude. Distinct genera represent each other in the same latitudes of the New and Old Worlds; and also, in a great degree, in Africa and Asia. But the development of an Orang out of a Chimpanzee, or reciprocally, is physiologically inconceivable,

The order Ruminantia is principally represented by Old World species, of which 162 have been defined; whilst only 24 species have been discovered in the New World, and none in Australia, New Guinea, New Zealand, or the Polynesian Isles.

The Camelopard is now peculiar to Africa; the Musk-deer to Africa and Asia: out of about 50 defined species of Antelope, only one is known in America, and none in the central and southern divisions of the New World. The Bison of North America is distinct from the Bison of Europe. The Musk-ox alone, peculiar for its limitation to high northern latitudes, roams over the arctic coasts of both Asia and America. The Deer-tribe are more widely distributed. The Camels and Dromedaries of the Old World are represented by the Llamas and Vicugnas of the New. As, in regard to a former (tertiary) zoological period, the fossil *Camelidæ* of Asia are of the genus *Camelus*, so those of America are of the genus *Auchenia*. This geographical restriction ruled prior to any evidence of man's existence.

Palæontology has expanded our knowledge of the range of the Giraffe: during miocene or old pliocene periods, species of *Camelopardalis* roamed in Asia and Europe. Passing to the non-ruminant Artiodactyles, geology has also taught us that the Hippopotamus was not always confined, as now, to African rivers, but bathed, during pliocene times, in those of Asia and Europe. But no evidence has yet been had that the Giraffe or Hippopotamus were ever other than Old World forms of *Ungulata*.

With respect to the Hog-tribe, we find that the true Swine (*Sus*) of the Old World are represented by Peccaries (*Dicotyles*) in the New; and geology has recently shown that tertiary species of *Dicotyles* existed in North as well as South America. But no true *Sus* has been found fossil in either division of the New World, nor has a *Dicotyles* been found fossil in the Old World of the geographer. *Phacochœrus* (Wart-hogs) is a genus of the Hog-tribe at present peculiar to Africa.

The Rhinoceros is a genus now represented only in Asia and Africa; the species being distinct in the two continents. The islands of Java and of

Sumatra have each their peculiar species; that of the latter being two-horned, as all the African Rhinoceroses are. Three or more species of two-horned Rhinoceros formerly inhabited Europe—one of them warmly clad, for a cold climate; but no fossil remains of the genus have been met with save in the Old World of the geographer. One of the earliest forms of European Rhinoceros was devoid of the nasal weapon.

Geology gives a wider range to the Horse and Elephant kinds than was cognizant to the student of living species only. The existing *Equidæ* and *Elephantidæ* properly belong to the Old World; and the Elephants are limited to Asia and Africa, the species of the two continents being quite distinct. The horse, as Buffon remarked, carried terror to the eye of the indigenous Americans, viewing the animal for the first time, as it proudly bore their Spanish conqueror. But a species of *Equus* coexisted with the *Megatherium* and *Megalonyx* in both South and North America, and perished apparently with them, before the human period.

Elephants are dependent chiefly upon trees for food. One species now finds conditions of existence in the rich forests of tropical Asia; and a second species in those of tropical Africa. Why, we may ask, should not a third be living at the expense of the still more luxuriant vegetation watered by the Oronooko, the Essequibo, the Amazon, and the La Plata, in tropical America? Geology tells us that at least two kinds of Elephant (*Mastodon Andium* and *Mast. Humboldtii*) formerly did derive their subsistence, along with the great Megatherioid beasts, from that abundant source. Nay more; at least two other kinds of Elephant (*Mastodon ohioticus* and *Elephas texianus*) existed in the warm and temperate latitudes of North America. Twice as many species of Mastodon and Elephant, distinct from all the others, roamed in pliocene times in the same latitudes of Europe. At a later or pleistocene period, a huge elephant, clothed with wool and hair, obtained its food from hardy trees, such as now grow in the 65th degree of north latitude; and abundant remains of this *Elephas primigenius* (as it has been prematurely called, since it was the last of our British elephants) have been found in temperate and high northern latitudes in Europe, Asia, and America. This, like other Arctic animals, was peculiar in its family for its longitudinal range. The Musk Buffalo was its contemporary in England and Europe, and still lingers in the northernmost parts of America.

I have received evidences of Elephantine species from China and Australia, proving the proboscidian pachyderms to have been the most cosmopolitan of hoofed herbivorous quadrupeds.

We may infer that the general growth of large forests, and the absence of deadly enemies, were the main conditions of the former existence of Elephantine animals over every part of the globe. We have the most pregnant proof of the importance of Palæontology in rectifying and expanding ideas deduced from recent Zoology of the geographical limits of particular forms of animals, by the results of its application to the proboscidian or Elephantine family. But such retrospective views of life in remote periods in many important instances confirm the zoologist's deductions of the originally restricted range of particular forms of mammalian life. This is the case with respect to that singular group of quadrupeds forming the Order BRUTA, Linn., or EDENTATA, Cuv. If a zoological province be defined by the proportion of genera and species peculiar to it, South America must be assigned as such province for the *Bruta*; three out of five of the genera, and a much larger proportion of the species, being peculiar to that continent. The Sloths (*Bradypus*), the Anteaters (*Myrmecophaga*), and the Armadillos (*Dasypus*), are the South American genera, or rather families, of *Bruta* referred to. The scaly Anteaters or Pangolins (*Manis*) are represented by long-tailed species in Africa, and shorter-tailed ones in Asia. The *Orycteropus* is represented by a single species in South Africa.

Fossil remains of the order *Bruta* have been discovered in tertiary beds in Europe and in America. The European fossil was a large Pangolin, and the discovery shows the natural extent of that province, now imperfectly divided into Europe, Asia, and Africa, to which the *Manis*-form of *Bruta* is and has been peculiar.

Geology also extends the geographical range of the Sloths and Armadillos from South to North America; but the deductions from recent rich discoveries of huge terrestrial forms of Sloth, of gigantic Armadillos, and large Anteaters, go to establish the fact that these peculiar families of the order *Bruta* have ever been, as they are now, peculiar to America; that several genera, including the largest species, have perished; and that the range of their still existing diminutive representatives has been reduced to the southern division of the 'New World.'

In no other region of the globe than America—that to which the Sloths, Anteaters, and Armadillos are now peculiar—has any fossil relic of an animal of those families been found: and if it be objected to this evidence of the primeval limitation of those families to America, that it is chiefly 'negative,' I would remark, that bones of the Megatherium are as likely to catch the eye as those of the Elephant; and would ask, if Megatherioids had co-existed with Elephants in other continents, as Elephants did with them in America, why have not their remains been found elsewhere? The positive and abundant evidence, however, of the remains of gigantic Sloths and Armadillos in South America is most conclusive of the original location of these unmigratory beasts in the New World.

Australia, which in extent of dry land merits to be regarded as a fifth continent, has a more restricted and peculiar character of aboriginal mammalian population than South America. It is emphatically the 'province' of those quadrupeds the females of which are provided with a pouch for the transport and protection of their prematurely born young.

One genus of *Marsupialia* (*Didelphys* or Opossums, properly so called) is peculiar to America, and is there the sole representative of the order. A small Kangaroo, and a few Phalangers, exist in islands that link the Malayan Archipelago with the Australian world. All the other marsupial genera, indeed every known genus save *Didelphys*, are found in Australasia, comprising New Guinea, Australia, and Tasmania.

The Kangaroos, Potoroos, Wombats, Koalas, Phalangers, Petaurists, Dasyures, and marsupial quadrupeds of insectivorous and carnivorous habits, distinguished only by scientific names, here perform the parts assigned to non-marsupial Mammalia in the Old World. No existing marsupial quadruped has been found native in continental Asia, in Africa, or in Europe.

Of the Australasian marsupials the species of New Guinea are distinct, and some of them subgenerically, from those of Australia proper.

Certain genera, as *Tarsipes*, *Chœropus*, *Phascolarctus*, are peculiar to Australia; other genera, as *Thylacinus* and *Sarcophilus*, the largest and most destructive of carnivorous marsupials, are peculiar to Tasmania.

No marsupial fossil has been found in the pliocene or pleistocene deposits of Europe, Asia, or Africa. In America, only representatives occur of the peculiarly American genus *Didelphys*. In the formations of these recent tertiary periods, and in the limestone caverns, of Australia, abundance of mammalian fossils have been found, and, with the exception of a single tooth of a Mastodon, every one of them has proved to be a marsupial species. Many belong to the genus of Kangaroos (*Macropus*), some to that of Potoroos (*Hypsiprymnus*); a few to the Wombats (*Phascolomys*), Dasyures (*Dasyurus*), and other existing genera. Some of these fossils have shown that the *Thylacinus* and *Sarcophilus* formerly inhabited Australia as well as Tasmania. Others exhibit the carnivorous or Dasyurine modification of the marsupial type in species equalling the Leopard and the Lion in size; and the latter with modifications of the carnassial teeth of generic value. We now know that there once existed in Australia species of Wombat equalling the Tapir in stature; and species most nearly allied to *Macropus*, but with characters of *Phascolomys* and *Phascolarctus* combined, which rivalled the Ox and Rhinoceros in bulk. The skull of the *Nototherium* presents the strangest proportions and features hitherto seen in the mammalian class: that of the *Diprotodon* is 3 feet in length, and combines the scalpriform incisors of the Wombat with the double-ridged molars of the Kangaroo.

The sum of all the evidence from the fossil world in Australia proves its mammalian population to have been essentially the same in pleistocene, if not pliocene times, as now; only represented, as the Edentate mammals in South America were then represented, by more numerous genera, and much more gigantic species, than now exist.

But geology has revealed more important and unexpected facts relative to the marsupial type of quadrupeds.

In the miocene and eocene tertiary deposits, marsupial fossils of the American genus *Didelphys* have been found, both in France and England; and they are associated with Tapirs like that of America. In a more ancient geological period, remains of marsupials, some insectivorous, as *Spalacotherium* and *Triconodon*, others with teeth like the peculiar premolars in the Australian genus *Hypsiprymnus*, have been found in the upper oolite of the Isle of Purbeck *. In the lower oolite at Stonesfield, Oxfordshire, marsupial remains have been found having their nearest living representatives in the Australian genera *Myrmecobius* and *Dasyurus*.

Thus, it would seem, that the deeper we penetrate the earth, or, in other words, the further we recede in time, the more completely are we absolved from the present laws of geographical distribution. In comparing the mammalian fossils found in British pleistocene and pliocene beds, we have often to travel to Asia or Africa for their homologues. In the miocene and eocene strata some fossils occur which compel us to go to America for the nearest representatives. To match the mammalian remains from the English oolitic formations, we must bring species from the Antipodes.

These are truly most suggestive facts, unrecognized until science looked abroad upon the world. If the present laws of geographical distribution depend, in an important degree, upon the present configuration and position of continents and islands, what a total change in the geographical character of the earth's surface must have taken place since the 'Stonesfield slate' was deposited in what now forms the county of Oxfordshire!

These and the like considerations from the modifications of geographical distribution of particular forms or groups of animals warn us how inadequate must be the phenomena connected with the present distribution of land and sea to guide to the determination of the primary ontological divisions of the earth's surface. Some of the latest contributions to this most interesting branch of Natural History have been the result of endeavours to determine whether, and how many, distinct creations of plants and animals have taken place. But, I would submit, that the discovery of two portions of the globe, of which the respective Faunæ and Floræ are different, by no means affords the requisite basis for concluding as to distinct acts of creation.

Such conclusion is associated, perhaps unconsciously, with the idea of the historical date of creative acts: it presupposes that the portion of the globe so investigated by the botanist and zoologist has been a separate and primitive creation,—that its geographical limits and features are still in the main what they were when the creative fiat went forth.

But Geology has demonstrated that such is by no means the case with respect to the portions of dry land now termed continents and islands. The incalculable vistas of time past into which the same science has thrown light are also shown to have been periods during which the relative positions of land and sea have been ever changing.

Already the directions, and to a certain extent the forms of the submerged tracts that once joined what now are islands to continents, and which once united now separate or nearly disjoined continents by broad tracts of conti-

* These fossils are due to the researches of Messrs. Brodie and Beckles.

nuity, begin to be laid down in geological maps, addressing to the eye such successive and gradually progressive alterations of the earth's surface.

These phenomena shake our confidence in the conclusion that the Apteryx of New Zealand and the Red-grouse of England were distinct creations in and for those islands respectively. Always, also, it may be well to bear in mind that by the word 'creation,' the zoologist means 'a process he knows not what.' Science has not yet ascertained the secondary causes that operated when "the earth brought forth grass and herb yielding seed after its kind," and when "the waters brought forth abundantly the moving creature that hath life." And supposing both the fact and the whole process of the so-called 'spontaneous generation' of a fruit-bearing tree, or of a fish, were scientifically demonstrated, we should still retain as strongly the idea, which is the chief of the 'mode' or 'group of ideas' we call 'creation,' viz. that the process was ordained by and had originated from an all-wise and powerful First Cause of all things.

When, therefore, the present peculiar relation of the Red-grouse (*Tetrao scoticus*) to Britian and Ireland—and I cite it as one of a large class of instances in Geographical Zoology—is enumerated by the zoologist as evidence of a distinct creation of the bird in and for such islands, he chiefly expresses that he knows not how the Red-grouse came to be there, and there exclusively; signifying also, by this mode of expressing such ignorance, his belief that both the bird and the islands owed their origin to a great first Creative Cause.

And this analysis of the real meaning of the phrase 'distinct creation' has led me to suggest whether, in aiming to define the primary zoological provinces of the globe, we may not be trenching upon a province of knowledge beyond our present capacities; at least in the judgment of Lord Bacon, commenting upon man's efforts to pierce into the 'dead beginnings of things.'

This at least is certain, that, being aware of former operations requiring to be well understood before we can draw conclusions as to other facts related to the unknown operations, one writes to no purpose in affirming conclusions without such preliminary knowledge.

Thus, the changing level of the land part of the earth's crust, throughout geological time, leads to the recognition of the present shape and size of continents and islands as being recent and temporary.

We feel that there have been phenomena attending, for example, the actual flow of continuous ocean between Ireland and Newfoundland, the nature and succession of which should be known in order to enable us to comprehend the causes or conditions of the present differences between the Flora and Fauna of those islands respectively: and so of every other part of dry land now circumscribed by sea.

All affirmations as to the time, place, and kind of origin of the organisms of a so circumscribed land, in the absence of a knowledge of the causes and conditions of such circumscription, must be guess-work.

It is a part of sound knowledge to be able to recognize the subjects regarding which we have not, at present, the basis of true assertion.

On the few occasions in which I have been led to offer observations on the probable cause of the extinction of species, the chief weight has been given to those gradual changes in the conditions of a country affecting the due supply in sustenance to animals in a state of nature. I have also pointed out the characters in the animals themselves calculated to render them most obnoxious to such extirpating influences; and on one occasion* I have applied the remarks to the explanation of so many of the larger species of particular groups of animals having become extinct, whilst smaller species of equal antiquity have remained.

In proportion to its bulk is the dificulty of the contest which, as a living organized whole, the individual of such species has to maintain against the surrounding agencies that are ever tending to dissolve the vital bond and subjugate the living matter to the ordinary chemical and physical forces. Any changes, therefore, in such external agencies as a species may have been originally adapted to exist in will militate against that existence in a degree proportionate, perhaps in a geometrical ratio, to the bulk of the species. If a dry season be gradually prolonged, the large mammal will suffer from the drought sooner than the small one; if such alteration of climate affect the quantity of vegetable food, the bulky Herbivore will first feel the effects of stinted nourishment; if new enemies are introduced, the large and conspicuous quadruped or bird will fall a prey, whilst the smaller species conceal themselves and escape. Smaller animals are usually, also, more prolific than larger ones.

"The actual presence, therefore, of small species of animals in countries where larger species of the same natural families formerly existed, is not the consequence of any gradual diminution of the size of such species, but is the result of circumstances, which may be illustrated by the fable of the 'Oak and the Reed;' the smaller and feebler animals have bent and accommodated themselves to changes which have destroyed the larger species."

Accepting this explanation of the extirpation of species as true, Mr. Wallace† has recently applied it to the extirpation of varieties; and, assuming, as is probable, that varieties do arise in a wild species, he shows how such deviations from type may either tend to the destruction of a variety, or to adapt a variety to some changes in surrounding conditions, under which it is better calculated to exist, than the type-form from which it deviated.

No doubt the type-form of any species is that which is best adapted to the conditions under which such species at the time exists; and as long as those conditions remain unchanged, so long will the type remain; all varieties departing therefrom being in the same ratio less adapted to the environing conditions of existence. But, if those conditions change, then

* On the Genus *Dinornis* (part iv.), Zool. Trans. vol. iv. p. 15 (February 1850).

† Proceedings of the Linnean Society, August 1858, p. 57.

the variety of the species at an antecedent date and state of things will become the type-form of the species at a later date, and in an altered state of things.

Mr. Charles Darwin had previously to Mr. Wallace illustrated this principle by ingenious suppositions, of which I select the following:—"To give an imaginary example from changes in progress on an island:—let the organization of a canine animal which preyed chiefly on rabbits, but sometimes on hares, become slightly plastic; let these same changes cause the number of rabbits very slowly to decrease, and the number of hares to increase; the effect of this would be that the fox or dog would be driven to try to catch more hares: his organization, however, being slightly plastic, those individuals with the lightest forms, longest limbs, and best eyesight, let the difference be ever so small, would be slightly favoured, and would tend to live longer, and to survive during that time of the year when food was scarcest; they would also rear more young, which would tend to inherit these slight peculiarities. The less fleet ones would be rigidly destroyed. I can see no more reason to doubt that these causes in a thousand generations would produce a marked effect, and adapt the form of the fox or dog to the catching of hares instead of rabbits, than that greyhounds can be improved by selection and careful breeding*."

Observation of animals in a state of nature is required to show their degree of plasticity, or the extent to which varieties do arise: whereby grounds may be had for judging of the probability of the elastic ligaments and joint-structures of a feline foot, for example, being superinduced upon the more simple structure of the toe with the non-retractile claw, according to the principle of a succession of varieties in time†.

Observation of fossil remains is also still needed to make known the antetypes, in which varieties, analogous to the observed ones in existing species, might have occurred, so as to give rise ultimately to such extreme forms as the Giraffe for example‡.

This application of palæontology has always been felt by myself to be so important that I have never omitted a proper opportunity for impressing the results of observations showing the "more generalized structures" of extinct as compared with recent forms of mammalia.

But, in pointing out how local changes might affect large quadrupeds, I

* Proceedings of the Linnean Society, August 1858, p. 49.

† "The powerful retractile talons of the falcon- and the cat-tribes have not been produced or increased by the volition of those animals; but among the different varieties which occurred in the earlier and less organized forms of these groups, *those always survived longest which had the greatest facilities for seizing their prey*."—Wallace, p. 61.

‡ "Neither did the giraffe acquire its long neck by desiring to reach the foliage of the more lofty shrubs, and constantly stretching its neck for the purpose; but because any varieties which occurred among its antetypes with a longer neck than usual *at once secured a fresh range of pasture over the same ground as their shorter-necked companions, and on the first scarcity of food were thereby enabled to outlive them*."—Ib. p. 61.

have refrained from speculating on dwarf-varieties surviving such influences as being the origin of existing representatives of extinct giants. A small sloth coexisted with the Megatherium, a small armadillo with the Glyptodon, the Apteryx with the Dinornis.

The aboriginal laws of geographical distribution of plants and animals have been modified from of old by geological and the concomitant climatal changes; but they have been much more disturbed by man since his introduction upon the globe.

The serviceable plants and animals which he has carried with him in his migrations have flourished and multiplied in lands the most remote from the habitats of the aboriginal species. Man has, also, been the most potent and intelligible cause of the extirpation of species within historic times.

He alone, with one of the beasts which he has domesticated—the dog—is truly cosmopolitan. The human species is represented by a few well-marked varieties; and there is a certain amount of correspondence between their localities and general zoological provinces: thus the Australian variety of man is as well-marked and circumscribed as the Australian fauna generally; the Papuans of New Guinea present the same difference from, with degree of affinity to, the Australians, as we find in comparing the respective faunæ of Papua and Australia. But, with regard to the alleged conformity between the geographical distribution of man and animals, which has of late been systematically enunciated, and made the basis of deductions as to the origin and distinction of the human varieties, I would submit the following remarks as affecting the system referred to*.

Using Blumenbach's term in the sense of the later terms 'Indo-European' and 'Aryan,' we find the 'Caucasian' race extended from Iceland to the mouth of the Ganges. There is no corresponding distinction in the animals and plants of the Europæo-Asiatic continent, which is bisected by the oblique line dividing the Mongolian from the Caucasian varieties of mankind. The Persian fauna extends into Tartary; the Himalayan into Thibet.

As two primary varieties of mankind exist in one great zoological province in the Old World, so a third great variety extends over at least two zoological provinces in the New World. All authors divide the North American or 'Nearctic' from the South American or 'Neotropic' region, whatever class of organic life they may treat of geographically; but the red or copper-coloured American is the same, physically and linguistically, to the extent of the characteristics of a primary race, from the 60th degree of north latitude to the 53rd degree of south latitude.

The Lapps of Arctic Europe differ linguistically and physically, as a race, from the Norwegians and Swedes: the zoological province is essentially one. As such it extends over the same parallels of latitude in America, where the Mongolian Esquimaux and the American Chippawas inhabit.

* Agassiz, in Gliddon and Nott's 'Types of Mankind,' 1854; and 'Indigenous Races of the Earth,' 1857.

The Hottentots and Caffres are more distinct, linguistically and physically, than the former are from equatorial Negroes, or the latter from the Nubians; yet they both inhabit one well-marked zoological province, South Africa.

Two varieties of mankind—the Papuan and Malayan—inhabit Borneo and other islands at the eastern part of the Indian Archipelago; these islands forming one and the same zoological and botanical province.

Not less than twenty colours have been found requisite to indicate in a map of the British Islands the different varieties and sub-varieties of the human race that have contributed to its miscellaneous population.

Other facts of the same kind might be cited, affecting the conformity of the distribution of man with that of the lower animals and plants, as absolutely enunciated in some recent works. Nor can we be surprised to find that the migratory instincts of the human species, with the peculiar endowment of adaptiveness to all climates, should have produced modifications in geographical distribution to which the lower forms of living nature have not been subject. It is only since man began to exercise his privilege and power, that the geographical laws in regard to the lower animals of existing species have begun to be blotted out.

Ethnology is a wide and fertile subject, and I should be led far beyond the limits of an inaugural discourse were I to indulge in an historical sketch of its progress. But I may advert to the uniform testimony of different witnesses—to the concurrence of distinct species of evidence—as to the much higher antiquity of the human race, than has been assigned it in historical and genealogical records.

Mr. Leonard Horner sagaciously discerned the value of the phenomena of the annual sedimentary deposits of the Nile in Egypt as a test of the lapse of time during which that most recent and still operating geological dynamic had been in progress. In two memoirs communicated to the Royal Society in 1855 and 1858, the results of ninety-five vertical borings through the alluvium thus formed are recorded.

The Nile sediment at the lowest depth reached is very similar in composition to that of the present day. In the lowest part of the boring of the sediment at the colossal statue in Memphis, at a depth of 39 feet from the surface of the ground, the boring-instrument is reported to have brought up a piece of pottery. This Mr. Horner infers to be a record of the existence of man 13,371 years before A.D. 1854; "of man, moreover, in a state of civilization, so far, at least, as to be able to fashion clay into vessels, and to know how to harden them by the action of a strong heat*."

Prof. Max Müller† has opened out a similar vista into the remote past of the history of the human race by the perception and application of analogies in the formation of modern and ancient, of living and dead languages.

* Proceedings of the Royal Society, Feb. 11, 1858, vol. ix. p. 128–134.

† 'Oxford Essays,' 1857.

From the relations traceable between the six Romance dialects, Italian, Wallachian, Rhœtian, Spanish, Portuguese, and French, an antecedent common 'mother-tongue' might be inferred, and consequently the existence of a race anterior to the modern Italians, Spanish, French, &c., with conclusions as to the lapse of time requisite for such divisions and migrations of the primitive stock, and for the modifications which the mother-language had undergone. History and preserved writings show that such common mother-race and language have existed in the Roman people and the Latin tongue.

But Latin, like the equally 'dead' language Greek, with Sanscrit, Lithuanian, Zend, and the Gothic, Slavonic, and Celtic tongues, can be similarly shown to be modifications of one antecedent common language; whence is to be inferred an antecedent race of men, and a lapse of time sufficient for their migration over a track extending from Iceland in the north-west to India in the south-east, and for all the above-named modifications to have been established in the common mother 'Arian' tongue.

The study of the animal kingdom has its practical results of national importance in relation to sources of food and beasts of traction and burden. Acts of Parliament relating to Fisheries, in order to realize their aims, must be based on physiological and zoological data. Animal physiology, the most important ground of successful medicine and surgery, is closely bound up with the right progress of zoology, of which, indeed, with zootomy, it is a branch. The great instrument of zoological science, as Lord Bacon points out, is a Museum of Natural History.

Every civilized state in Europe possesses such a Museum. That of England has been progressively developed to the extent which the restrictive circumstances under which it originated have allowed. The public is now fully aware, by the reports that have been published by Parliament, by representations to Government, and by articles in Reviews and other Periodicals, of the present condition of the National Museum of Natural History and of its most pressing requirements.

Of them the most pressing, and the one essential to rendering the collections worthy of this great empire, is 'space.' Our colonies include parts of the earth where the forms of plants and animals are the most strange. No empire in the world had ever so wide a range for the collection of the various forms of animal life as Great Britain. Never was there so much energy and intelligence displayed in the capture and transmission of exotic animals by the enterprising traveller in unknown lands and by the hardy settler in remote colonies, as by those who start from their native shores of Britain. Foreign Naturalists consequently visit England anticipating to find in her capital and in her National Museum the richest and most varied materials for their comparisons and deductions. And they ought to be in a state pre-eminently conducive to the advancement of a philosophical zoology, and on a scale commensurate with the greatness of the nation and the peculiar national facilities for such perfection.

But, in order to receive and to display zoological specimens, space must be had; and not merely space for display, but for orderly display: the galleries should bear relation in size and form with the nature of the classes respectively occupying them. They should be such "as to enable the student or intelligent visitor to discern the extent of the class, and to trace the kind and order of the variations which have been superinduced upon its common or fundamental characters." In the British Museum one gallery permits this to be done in regard to the class of Birds. "To show how the mammalian type is progressively modified and raised from the form of the fish or lizard to that of man; to illustrate the gradations by which one order merges into another; to impart to the visitor, by the arts of arrangement and juxtaposition, a knowledge of his own class akin to that which he derives from the collection of birds, would require a corresponding Mammalian Gallery*."

The same is to be said of the classes of Reptiles and Fishes, and of the Molluscous, Articulate, and Radiate Provinces.

An osteological collection is as indispensable to the illustration of the Vertebrata as a conchological one is to that of the Mollusca. Nor should the size of any of the skeletons be a bar to the obtainment of adequate space for the Osteological Collection in the National Museum of Natural History. The very fact of the Whales being the largest animals that now exist, or have at any period lived upon the earth, is that which makes it more imperative to illustrate the fact and gratify the natural interest of the public by the adequate and convenient exhibition of their skeletons.

In like manner, in the Palæontological collections or galleries of Fossil remains, the restoration of every extinct species, however bulky, should be carried out where practicable.

The locality of such adequately-sized Museum concerns the administrator and the public convenience. Reasons for its association with Ethnological Antiquities and the National Library have been assigned in a memorial to H. M. Government, and by the Deputation of cultivators of Science to the Chancellor of the Exchequer, and these reasons have been commented on in a late Number of the 'Quarterly Review.'

I am most concerned in advocating the pressing necessity of adequate space for the National Museum of Natural History, wherever administrative wisdom may see fit to locate it. And, wherever that Museum may ultimately stand, it is the duty of the Representative of Associated British Science here to urge that the Curator of each class of animals should have assigned to him the charge of delivering a public course of lectures on the characters, principles of classification, habits, instincts, and economical uses of such class.

* "Report to the Trustees of the British Museum from the Superintendent of the Natural History Departments, 7th January, 1857," Parliamentary printed Paper, 379, p. 23 (1858).

The most elaborate and beautiful of created things—those manifesting life—have much to teach—much that comes home to the business of man, and also to the highest elements of his moral nature. The nation that gathers together thousands of corals, shells, insects, fishes, birds, and beasts, and votes the requisite funds for preparing, preserving, housing and arranging them, derives the smallest possible return for the outlay by merely gazing and wondering at the manifold variety and strangeness of such specimens of Natural History.

The simplest coral and the meanest insect may have something in its history worth knowing, and in some way profitable. Every organism is a character in which Divine wisdom is written, and which ought to be expounded. Our present system of opening the book of Nature to the masses; as in the Galleries of the British Museum, without any provision for expounding her language, is akin to that which keeps the book of God sealed to the multitude in a dead tongue.

Finally, in reference to a National Museum of Natural History, I would respectfully solicit the attention of the Administrator to the successful working and unprecedented progress of the National Botanical Establishment at Kew, of the Museum of Practical Geology in Jermyn Street, and of the Museum of Practical Art at South Kensington, in reference to the relations of the eminent Directors of those establishments to Government. For this opens the question, whether in the event of acquiring, in whatever locality, the element essential to a National Museum of Natural History—space—any intermediate organization, unknown in the public establishments above cited, be really needed in the case of Natural History, in order to afford Parliament and the public the requisite guarantee of the good condition of the Collections, and the efficient discharge of the duties and functions of the National Museum of Natural History.

The sciences promoted by the statistical Section F., although bearing more immediately than any others on the prosperity of nations and the well-being of mankind, had no existence in the time of Bacon.

We look in vain for any evidence, for example, of a clear conception of Sanitary Science, or the doctrines preventive of disease, in the writings of that great philosopher and politician. The only approach to Statistics which we find in the 'Historia Vitæ et Mortis,' for example, is a collection of instances of longevity; and the main aim of that Essay seems to have been the extreme prolongation of particular or individual life, not the insurance of average longevity to the species. Some remarks on the advantage of pure air are congenial with the aims of the modern sanitary philosopher; but he finds no evidence of Bacon's conception of its importance to the masses, or of the means of ensuring it to populous cities, for prevention of plague and pestilence. Sanitary science, as a great power for mankind, in the Baconian sense, is of very recent growth: and, whether we consider the present evidence of its potency where it has been rightly applied, or the present evidence of the miserable results of its neglect, we must be stimulated to use every effort to promote its progress and impress its importance on all who may aid therein.

Long after Lord Bacon's day, the plague, the fever of the 'black assize,' and the like visitations, which drove Courts and Parliaments and Royal Societies from town to country, were met only by rude quarantine imprisonments of the sick, which greatly aggravated the sum of mortality. Accidents, such as the fire of London, subliming much old and vested filth, and followed by wider streets and better dwellings, produced results which opened the eyes of a few thinkers to the relation between certain physical conditions and the non-return of the plague.

Now, however, these relations have been comprehensively investigated; the diseases produced or aggravated by preventible conditions are well known; the most efficient and economical modes of prevention have been the subject of successful and convincing experiment. But men are slow to act where the profitable result is not direct. Health, we call, with cuckoo-cry, the greatest blessing; but practically it is daily sacrificed to ambition, wealth, pleasure, and a hundred aims in which duty takes no necessary part. That, however, is an affair of individual free-will with which abstract science has no business.

But in reference to inevitable aggregates of mankind, the nation is concerned in the science which seeks their especial bodily well-being. Fleets, armies, manufactories, workshops, the localities in towns where wage-people* congregate,—such are conditions of citizens in which it behoves the State, to the utmost constitutional extent of its power, to apply the ascertained means of preventing disease and death.

Perhaps the most exemplary instances of the value and economy of sanitary science are afforded by the records of the British Navy, especially since the period of Capt. Cook, whose name, were I to select one, as a prime promoter of the science, would be that which I should adduce with highest veneration. Some of the Arctic Expeditions, also, illustrate in an exemplary degree the value of preventive measures in maintaining health under difficult and depressing circumstances.

Our armies have yet to receive the benefit of what is now known in the prevention of death by disease. To what extent they have to benefit by it has been made plain by the results of recent investigations, in which the testimony of Florence Nightingale shines forth as the beacon which lights to better measures.

* I venture to propose this term as free from the objections that have been made to "lower orders," "humbler classes," "poorer classes," "working classes," "labouring population," &c. The two former are a reflection on those who are so designated; and the two latter are an implied reflection on all other classes, as if left to a life of vacant inoccupation. They are injuriously misleading terms. The true specific character of the great class in question is seen by the Naturalist to be "payment by wages"; it is the "wage-class."

The results of the labours of the Sanitary Commissioners in the Crimea, although the application of their preventive science was an after-thought, and late, must have convinced the most sceptical of military men of its importance. It became one of the elements of the ultimately superior condition of the English part of the Allied army*.

How large a proportion of loss in the French force was due to the absence of neglect of preventive measures, we learn from the recent 'Relation Medico-chirurgicale de la Campagne d'Orient' of M. Scrive, the head of the Medical Department of the French army during that campaign; and from the admirable paper on the same subject by Dr. Gavin Milroy, Member of the Sanitary Commission to the British Army in the East. To cite our neighbour's case, in which the organization of the land-service has a high repute, out of a force which averaged during a period of twenty months 104,000, upwards of 193,000 men were sent into hospital, *i. e.* at the rate of from 9000 to 10,000 per month. About one-fifth of these admissions were from wounds and mechanical injuries; the rest were from disease. The deaths in the hospitals at Constantinople amounted to 28,000; elsewhere, as in the camp and the field-ambulances, the deaths were 28,400, exclusive of 7500 slain in action. Of the 28,400 deaths under treatment, about 4000, or a seventh part of the whole, arose from gun-shot wounds and accidents, the other six-sevenths being the result of disease. The official returns give a total loss from all causes during the whole Crimean campaign of 70,000: it is believed to have exceeded that figure by 10,000. 65,000 men, out of 309,268, sent from France and Algeria, were invalided in consequence of disablement from wounds or the effect of disease.

Dr. Scrive points out that, if the buildings at Gallipoli had been inspected

* These results cannot be better stated than in the words of Miss Nightingale, in an appeal for the organization of a preventive administration, founded on the sanitary history of the Crimean campaign.

"It is," she says, "a complete example—history does not afford its equal—of an army, after a great disaster arising from neglect, having been brought into the highest state of health and efficiency. It is the whole experiment on a colossal scale. In all other examples, the last step has been wanting to complete the solution of the problem. We had, in the *first* seven months of the Crimean campaign, a mortality among the troops of 60 per cent. per annum, from disease alone,—a rate of mortality which exceeds that of the great plague of London, and a higher ratio than the mortality of the cholera to the attacks; that is to say, there died out of the army in the Crimea an annual rate greater than ordinarily die in time of pestilence out of the sick. We had, during the *last six* months of the war, a mortality among our *sick* not much more than among our *healthy* Guards at home; and a mortality among our troops, in the last five months, two-thirds only of what it is among our troops at home. The mortality among the troops of the line at home, when corrected, as it ought to be, according to the proportion of different ages in the service, has been, on an average of ten years, 18·7 per 1000 per annum, and among the Guards, 20·4 per 1000 per annum. Comparing this with the Crimean mortality, for the last six months of our occupation, we find that the deaths to admissions were 24 per 1000 per annum; and during the last five months, viz. January to May 1856, the mortality among the troops did not exceed 11·5 per 1000 per annum. Is not this the most complete experiment in army hygiene?"

and made fit for the purpose before they were occupied as an hospital, a regiment of active young soldiers might have been saved.

At Varna, a Turkish barrack within the walls was prematurely occupied as an hospital: it had to be abandoned after great loss of life. Fewer men fell in the unsuccessful attack upon the Malakoff on the 18th of June than succumbed in the rash attempt to use, as an hospital, a place which had not been previously fitted for one. And the time and labour required by the Sanitary Inspector to effect their fitness are as nothing compared with the preliminary approaches to the Malakoff, and with the delay and impediments caused by the prostration of a large proportion of effective force by disease.

Without consulting the medical staff, it was determined to move from Varna to the notoriously malarial region on the south of the Danube, called the Dobrudscha. On the 20th of July the first division of the army moved from Varna; on the 26th the cholera broke out. Hundreds of men were struck down at once, and died within a few hours after being seized: in one regiment 300 men were attacked within twenty-four hours, and most of them died on the spot. Appalled by the blow, the commanding officer retreated, as from before an overwhelming force; but, ere he could reach the healthier locality, one-third of the division had perished, and numbers reached the coast only to expire on the beach.

No enemy had been encountered save that one, of whose power and presence sanitary science had in vain forewarned the commander. On the return of the first division to Varna, a force of 12,000 had been reduced to 7000; the victims including two general officers and seven medical officers.

Not to weary by other special instances of the effect of neglecting preventive preparatory sanitary measures, I may sum up by the statement that one pestilence, in the marshes of the Danube, within two months, out of an army 55,000 strong, and before a shot had been fired, had destroyed as many men as were slain by the enemy in the field during the twelve months from the landing in the Crimea to the capture of Sebastopol, and when the army averaged double the above number of men.

That this pestilence, or its fatal effects, might have been, in an important degree, prevented by practicable applications of sanitary science is the conviction of the ablest medical officers of the French and English armies; and this conviction was substantiated by the results of the Sanitary Commission which operated in the English lines before Sebastopol. These authorities concur in the conclusion that three-fourths of the losses of an army in the field are not from the enemy or from unavoidable casualties of service, "but from diseases which are more or less under control." "Of these," writes Dr. Milroy, "typhus and scurvy are two of the most formidable, and the most easily preventible. They are the inevitable products of certain well-ascertained conditions, and they may be generated at will as surely as any salt or other compound may be formed by the chemist in his laboratory.

And yet it was these very evils which but two years ago brought the noble army of a mighty nation, at the close, too, of a glorious campaign, to almost the verge of destruction."

I may allude to one other point which sanitary science would suggest to the administrator in reference to the clearly-ascertained effects of too little pure air, and too much foul air inspired continuously during a given period.

The skilled soldier being of a given value when landed healthy and strong in the Crimea or at Calcutta, query, whether it be more economical to carry 1000 in one ship, landing 500 sick, enfeebled, and prepared to fall into and engender epidemics, or to carry the 1000 in two such ships, and land them healthy and fit for action? The same administrative question applies to barracks and hospitals.

One noble use and adequate application of so vast a triumph of naval architecture as Mr. Scott Russell's 'Leviathan' would be its carrying troops in good condition as regards health, for which its capacity especially fits it.

When authority becomes impressed with a conviction stimulating to action of the importance of sanitary science, it will insist on the possession, by the army medical officers, of the elements of that science as well as of the principles of practice in the cases of disease and the treatment of wounds. But, in order that an army may benefit by the doctors' knowledge of preventive medicine, authority should direct preliminary examinations and reports of sites for encampment,—of buildings for barracks and hospitals,—of clothes for extreme climates, and the like, and should command that such reports be acted upon, where no urgent circumstances or inevitable movements preclude the adoption of the means for the prevention of decimating fevers and choleras.

Bonaparte's military science was characterized by the rapid concentration of his forces upon a given point. A like success and superiority may attend the commander who keeps the greatest proportion of his men in good working trim. The healthier the man the longer and quicker will he march. And the care which foresees and provides for the efficient fighting order of a force is quite compatible with the most intrepid handling of that force in the field of battle.

As to the dense populations in civil life, the number of towns in England in which the sewage is rapidly, efficiently, and economically carried off by water-power and hydraulic apparatus, constitute so many experimental demonstrations of the success attending a proper unintermitting water-supply and co-adjusted system of tubular drainage. Lancaster, Penrith, Alnwick, Barnard Castle, Rugby, Croydon, Ely, are instances in which are demonstrated the diminution of fever and other causes of untimely death,—the augmentation of the cleanliness and comfort of the wage-classes,—the economy in the wear of all washable articles through the supplies of pure water, —collateral and unexpected economies in regard to fire-insurance, from the power of rapid extinction of conflagration which the unintermitting system affords,—the purity of the atmosphere in formerly fœtid courts and alleys,—these and other inestimable material advantages have resulted, and will result with progressively increased benefit as time goes on.

Lord Bacon observes, in his suggestions for an inquiry into the causes of death,—"And this inquiry, we hope, might redound to a general good, if physicians would but exert themselves and raise their minds above the sordid considerations of cure; not deriving their honour from the necessities of mankind, but becoming ministers to the Divine power and goodness both in prolonging and restoring the life of man; especially as this may be effected by safe, commodious, and not illiberal means, though hitherto unattempted. And certainly it would be an earnest of Divine favour, if, whilst we are journeying to the land of promise, our garments, these frail bodies of ours, were not greatly to wear out in the wilderness of this world."

Amongst his special topics of inquiry are these:—

"Inquire into the length and shortness of men's lives according to the times, countries, climates, and *places* in which they were born and lived."

"Inquire into the length and shortness of men's lives according to their food, diet, manner of living, exercise, and the like. With regard to the *air* in which they live and dwell, I consider that ought to be inquired into under the former article concerning *their places of abode*."

Now these inquiries have in our times been made chiefly in the form and by the authority of Sanitary Commissions; in the successful working of which the name of EDWIN CHADWICK stands foremost.

By these commissions it has been shown, as a general result, that nearly one-half the prevalent diseases are due to one or other form of atmospheric impurity; impurity from decomposing fæcal or animal and vegetable matter, within and without human habitations, and beneath the sites of towns, and atmospheric impurity from over-crowding.

For the prevention of the diseases arising from these causes, the sanitary physician must direct his requisitions not to the apothecary, but to the professor of new arts, which are only partially created,—the art of the sanitary architect and the art of the sanitary engineer. The latter has already been officially shown how he may collect water from natural and artificial springs, convey it into houses unintermittingly fresh, and without stagnation, and by its means remove from houses, through self-cleansing drains and self-cleansing sewers, constantly and before noxious decomposition can commence, all fæcal and waste animal and vegetable matter.

In model dwellings, where the sanitary conditions have been as yet applied only in a rudimentary manner, the death-rate has, in fact, been steadily kept down to thirteen in a thousand, or much less than one-half that which prevailed in London when Bacon lived, or little more than one-half of the death-rate which prevails there now. In fact, it is proved to be practicable to make those garments—the frail bodies of the population—last full ten years, or probably one-third longer, in the wilderness of this world.

In our time physicians have ably exerted themselves in aid of the sanitary engineer and administrator. Their general sentiments have been long expressed in such terms as those of Dr. Willis of Kelso:—"It is impossible to avoid the conclusion that much more might still be accomplished could we be induced to profit by a gradually extending knowledge, so as to found upon it a more wisely directed practice. When man shall be brought to acknowledge (as truth must finally constrain him to acknowledge) that it is by his own hand, through his neglect of a few obvious rules, that the seeds of disease are most lavishly sown within his frame, and diffused over communities; when he shall have required of medical science to occupy itself rather with the prevention of maladies than with their cure; when governments shall be induced to consider the preservation of a nation's health an object as important as the promotion of its commerce or the maintenance of its conquests, we may hope then to see the approach of those times when, after a life spent almost without sickness, we shall close the term of an unharassed existence by a peaceful euthanasia."

It is to the landlord,—to the representative landlords and owners of habitations,—in parliament, to whom exhortations are now required to be addressed, to raise their minds above "the sordid considerations" of the expenses of cure, that is, of the expenses of those sanitary works of combined drainage and water-supply, which it is their province to provide.

It is right, however, to state that advances in well-directed practical applications of sanitary science are advances in economy; that two houses and two towns may receive constant supplies of water at the expense formerly incurred for supplying one on the intermittent system, with its stagnancy and pollutions in house cisterns and large storage reservoirs. It remains for the legislature and local administrations to make prevalent that which is proved to be practicable for the public good, and to ensure that good at the economical rate at which particular instances afford demonstrations that it is achievable.

Agriculture has of late years made unusual progress in this country, and much of that progress is due to the application of scientific principles; chiefly of those supplied by chemistry, in a less degree of zoology and physiology: some minor help in regard to the more effectual abatement of noxious insects has been had from entomology; recent discoveries of the metamorphoses, metagenesis, and the course and modes of transmission of internal parasites, have afforded a rational explanation of some traditional precautionary rules of herdsmen, in reference to the 'rot' in sheep, from fluke-worms and hydatids; and more direct power of preventing epizootics will doubtless be obtained from entozoology.

Geology now teaches the precise nature and relations of soils, a knowledge of great practical importance in guiding the drainer of land in the modifications of his general rules of practice. Palæontology has brought to light unexpected sources of valuable manures, in phosphatic relics of ancient animal life, accumulated in astounding masses in certain localities of England, as, for instance, in the red-crag of Suffolk, and the greensands of Cambridge.

But enormous quantities of azotic, ammoniacal, and phosphatic matters are still suffered to run to waste; and, as if to bring the wastefulness more home to conviction, these products, so valuable when rightly administered, become a source of annoyance, unremunerative outlay, and disease, when, as at present in most towns, imperfectly and irrationally disposed of.

For the most part, thought is taken only how to get rid of these products in the easiest and quickest way. The metropolitan authorities have hitherto carried the chain of reasoning no further. They have turned them into the Thames, the receptacle nearest at hand; but in so doing have failed in their prime intention. The metropolis is not even rid of its excreta; but they have returned upon it and accumulated, with increased noxious and morbific power, on the strands of the valley that bisects it; appealing, as is notorious, summer after summer, to the very legislature itself, with unintermitting and importunate odours, compelling the attention of the possessors of lands and houses to this important subject.

Now here I would beg leave to remark that, in the operations of Nature, there is generally a succession of processes coordinated for a given result: a peach is not directly developed as such from its elements; the seed would, *a priori*, give no idea of the tree, nor the tree of the flower, nor the fertilized germ of that flower of the pulpy fruit in which the seed is buried. It is eminently characteristic of the Creative Wisdom, this far-seeing and prevision of an ultimate result, through the successive operations of a coordinate series of seemingly very different conditions.

The further a man discerns, in a series of conditions, their cordination to produce a given result, the nearer does his wisdom approach—though the distance be still immeasurable—to the Divine wisdom.

One philanthropist builds a fever-hospital, another drains a town. One crime-preventer hangs the man, another trains the boy. One financier would raise money by augmenting a duty, or by a direct tax, and finds the revenue not increased in the expected ratio. Another diminishes a tax, or abolishes a duty, and through foreseen consequences the revenue is improved.

Quarantine exemplifies only the first step in the progress of thought, bearing on the prevention of a dreaded distemper. It is a system which might keep out contraband goods or uncertified strangers, but it is powerless against the gaseous factors of plague, cholera, or yellow fever. No European country suffers more from such maladies than Naples or Portugal, where quarantine regulations are most stringent.

Agriculture, let me repeat, has made and is making great and encouraging progress. But much yet remains to be done. Were agriculture adequately advanced, the great problem of the London sewage would be speedily solved.

Can it be supposed, if the rural districts about the metropolis were in a condition to avail themselves of a daily supply of pipe-water not more than equivalent to that which a heavy shower of rain throws down on 2000 acres of land, but a supply charged with 30 tons of nitrogenous ammoniacal principles, that such supply would not be forthcoming, and made capable of being distributed when called for within a radius of 100 miles? I believe that, were the call made as loudly as it undoubtedly would be under the exigencies of a more advanced stage of agricultural mechanics, the skill of our engineers, with the constructive powers of our machine-makers, both carried to a degree of perfection which the world never before saw, would speedily and successfully meet the call, and leave nothing but the rainfall of the metropolis to seek its natural receptacle—the Thames.

To send ships for foreign ammoniacal or phosphatic excreta to the coast of Peru, and to pollute by the waste of similar home products the noble river bisecting the metropolis, and washing the very walls of our Houses of Parliament, are flagrant signs of the desert and uncultivated state of a field where science and practice have still to cooperate for the public benefit.

To promote this cooperation, effectual aid may be given by a recently established kindred Association, through the advancement of the legislative and administrative sciences. For it is the present condition of those social sciences which forms the chief obstacle to the practical application of Sanitary science. Of this science, it may be confidently averred that, besides providing means for the relief of town-populations from excessive sickness, it has, in a sufficient number of instances, provided means for the prevention of the pollution of rivers as well as for applying the manure of towns to fertilize the land.

The application of those means now rests with the Legislator and Administrator, and involves questions which are not within the province of the British Association*.

Some of our sciences are deeply concerned in one progressive step,—the uniformity of standard in measure and weight throughout the civilized world; in urging on which step, energetic and unwearied efforts are now being made by a Committee of our fellow-labourers of the Royal Society of Arts, amongst whom the name of the prime promoter of this and kindred reforms, Mr. James Yates, deserves especial and honourable mention.

Chemistry is more concerned in the uniform expression of the results of her delicate balances amongst her cultivators of different countries: Natural History is no less interested in the use, by all observers, of one and the same scale for measuring, and of one set of terms for expressing the superficial dimensions of her subjects. Practically, I may state that I have found the

* Services on three successive Sanitary Commissions, on the First Consolidated Metropolitan Sewers Commission, and at the Board of Health, have led me to enter at undue length on Sanitary matters, and are pleaded in excuse.

French mètre, and its subdivisions down to the millimètre, adequate to give all the needful data of this kind for comparison of superficial dimensions in the varied and extensive range of objects to which my business and pursuits have led me to pay attention. Of the hindrances to progress and inconveniences of the 'foot,' the 'inch,' and its duodecimal parts or lines,—rarely the same in any two countries,—I have elsewhere spoken and argued.

The whole subject of a uniform system of weights, measures, and current coin, will occupy the attention of a section of the Association for the Advancement of Social Science, which will meet at Liverpool shortly after the termination of the present Meeting. This is by no means the only point at which the Natural and Social Sciences touch and react on each other with mutual advantage. The proximity of the periods of the annual assemblage of the promoters of these respective sciences, together with the occurrence of both, this year, in the North of England, is favourable to the fruition of such advantages, by facilitating attendance at both Associations: and in future years, the conditions of time and place of meeting, making it easy for a Member of the British Association to attend also the Association for Social Science, and reciprocally, might, with a view to mutual advantage and cooperation, be a subject worthy of the consideration of the respective Councils of those Bodies.

In reference to the relations now subsisting between the State and Science, my first duty is to express our grateful sense of such measure of aid, cooperation, and countenance as has been allotted to Scientific Bodies, Enterprises and Discoveries; more especially to acknowledge how highly we prize the sentiments of the Sovereign towards our works and aims, manifested by spontaneous tribute to successful scientific research, in honourable Titles and Royal gifts, and above all, in the gracious expressions accompanying them, with which Her Majesty has been pleased to distinguish some of our Body. Happy are we, under the present benignant Reign, to have, in the Royal Consort, a Prince endowed with exemplary virtues, and with such accomplishments in Science and Art as have enabled His Royal Highness effectually, and on some memorable occasions, in the most important degree, to promote the best interests of both. We rejoice, moreover, in the prospect of being favoured at a future Meeting by the Presidency of the Prince Consort; and that, ere long, this Association may give the opportunity for the delivery of another of those 'Addresses,' pregnant with deep thought, good sense, and right feeling, which have placed the name of Prince Albert high in the esteem of the Intellectual Classes, and have engraven it deeply in the hearts of the humblest of Her Majesty's subjects.

On the part of the State, sums continue to be voted in aid of the means independently possessed by the British Museum and the Royal Society, whereby the Natural History Collections in the first are extended, and the more direct scientific aims of the latter Institution are advanced. The

Botanical Gardens and Museum at Kew, and the Museum of Practical Geology in Jermyn Street, are examples of the National Policy in regard to Science, of which we can hardly over-estimate the importance. Most highly and gratefully also do we appreciate the cooperation of the 'Board of Trade' with our Meteorologists, by the recent formation of the Department for the collection of meteorological observations made at sea.

But not by words only would, or does, Science make return to Governments fostering and aiding her endeavours for the public weal. Every practical application of her discoveries tends to the same end as that which the enlightened Statesman has in view.

The steam-engine in its manifold applications, the crime-decreasing gas-lamp, the lightning conductor, the electric telegraph, the law of storms and rules for the mariner's guidance in them, the power of rendering surgical operations painless, the measures for preserving public health and for preventing or mitigating epidemics,—such are amongst the more important practical results of pure scientific research with which mankind have been blessed and States enriched. They are evidence unmistakeable of the close affinity between the aims and tendencies of Science and those of true State policy. In proportion to the activity, productivity, and prosperity of a community is its power of responding to the calls of the Finance Minister. By a far-seeing one, the man of Science will be regarded with a favourable eye, not less for the unlooked-for streams of wealth that have already flowed, but for those that may in future arise, out of the applications of the abstract truths to the discovery of which he devotes himself.

This may, indeed, demand some measure of faith on the part of the practical Statesman. For who that watched the philosophic Black experimenting on the abstract nature of Caloric could have foreseen that his discovery of latent heat would be the stand-point of Watt's invention of a practically operative steam engine! How little could the observer of Oersted's subtle arrangements for converting electric into magnetic force have dreamt of Wheatstone's application of such discovery to the rapid interchange of ideas now daily practised between individuals in distant cities, countries, and continents!

Some medical contemporaries of John Hunter, when they saw him, as they thought, wasting as much time in studying the growth of a deer's horn as they would have bestowed upon the symptoms of their best patient, compassionated, it is said, the singularity of his pursuits. But, by the insight so gained into the rapid enlargement of arteries, Hunter learnt a property of those vessels which emboldened him to experiment on a man with aneurism, and so to introduce a new operation which has rescued from a lingering and painful death thousands of his fellow-creatures. Our great inductive physiologist, in his dissections and experiments on the lower animals, was "taking light what may be wrought upon the body of man."

The production of chloroform is amongst the more subtle experimental results of modern chemistry. The blessed effects of its proper exhibition in the diminution of the sum of human agony are indescribable. But that divine-like application was not present to the mind of the scientific chemist who discovered the anæsthetic product, any more than was the gas-lit town to the mind of PRIESTLEY or the condensing-engine to that of BLACK.

These unexpected applications of pure Science, fraught with such incalculable influences on the well-being of peoples, ought to weigh with the Minister to whom may be submitted an enterprise in Science which only a nation can undertake, or the considerations of a scientific establishment which none but a nation can support. Much of the improvement in refined machinery, and the tools for making it, grew out of the requirements and teaching of BABBAGE during the construction of his Calculating Machines. Such collateral result, alone, has made a manifold return for the sum granted in aid of the realization of that philosopher's great idea. So rare a combination of analytic, inventive, and constructive faculties is seldom given to man; and the generation witnessing such a mind in operation would be wise to secure the full result of its peculiarly directed energy.

In proportion to the facilities and rapidity of exchange and transit of goods, of men, and of thought, trade and commerce expand; and with their expansion grow the receipts under the heads of Customs and Excise. Every application of pure mathematics and astronomy to the making voyages safer and speedier,—every observation by such instruments as the Establishment of the British Association at Kew perfects for their purpose, giving to the mariner fore-knowledge of storms, and teaching him their course and lines of greatest intensity,—becomes an important condition in enabling a country to bear the burthen of taxation.

The steps in the series of this relation have been so plain that national encouragement has long been given to Astronomy. As clear a perception of the same relation and tendency of discoveries in Chemistry, Electricity, Electro-magnetism, and other sciences, led Herschel, long ago, to ask "Why the direct assistance afforded by Governments to the execution of continued series of observations should be confined to Astronomy?"

Faithfully is the State served by that Science. Most exemplary are those observations made, and every astronomical duty bearing on the interests of society, discharged, in the Royal Observatory at Greenwich, the good repute of which grows and spreads year by year under its present indefatigable Chief. Year by year, almost, arises the necessity for some additional instrument to meet the ever-expanding relations and requirements of Astronomy and Meteorology.

But to make use of fitting instruments is one thing, to make them fit for use another. To perfect that fitness and extend it to the instruments of all observatories, to maintain a standard of excellence whereby comparison of results shall be most productive of truth, are the special functions of our kindred establishment at Kew. There, as in the mathematical and engine houses of the 'New Atlantis,' we seek to render our instruments unrivalled "for equality, fineness, and subtilty" of operation. No expense, time, or pains have been spared by this Association to bring the exquisitely constructed and ingeniously adjusted mechanisms required to give us cognizance of the operations of the mysterious influences pervading our earth and atmosphere to their utmost attainable exactitude of performance.

To prepare, to adjust, to test, verify, and rectify those instruments for the use of voyagers and travellers are labours that have grown out of the important function of the 'Kew Observatory.'

These labours have been cheerfully performed whenever and by whomsoever required; as, recently, at the request of the Admiralty and Royal Society in aid of the Commission for determining the Oregon Boundary, and in the Second Expedition of Livingstone to the Zambesi. Not only have philosophical instruments been prepared and constants determined, but the voyagers have received, at Kew, practical instructions in their use.

The reputation of the accuracy of the instruments at our establishment is now such that requests are received from different Foreign States for a like application of the resources which it commands. The United States, Russia, Austria, Portugal, the Papal States for the 'Collegio Romano,'—all have testified, by such applications for the preparation and adjustment of philosophical instruments, that the establishment, originated and organized by the British Association, fulfils a national scientific want. Our 'Report' this year will show that the Admiralty, the Board of Trade, and other Home-institutions give the same testimony.

With the growth of its reputation and experience of its utility, the labours carried on at Kew have necessarily multiplied; and the expense of the establishment cannot be this year less than £800.

Were the duties of the Kew Observatory superadded to those performed at Greenwich, such expense would fall, in the ordinary course, upon the State. Hitherto it has been borne by the British Association, and to that extent cripples our power of lending the helping hand to other scientific work.

We have to thank the Government for the use of the building at Kew.

Such pecuniary aid as has been added to the sums allotted from our subscriptions has been received from a kindred self-supporting Scientific Association. The Royal Society liberally voted the amount required for the purchase of the "Whitworth's Lathe and Planing Machine," now doing efficient work at the Observatory.

In the late location, by liberal permission of the Government, of the Royal, Linnæan, and Chemical Societies in contiguous apartments at Burlington House, we hail the commencement of that organization, recommended by the British Association at their first meeting, from which the most important results of combination of present scattered powers, and of a system of intellectual cooperation, may be confidently expected. "The combined advantages, including at once the most powerful stimulus and the most efficient guidance of scientific research," have appeared to an eminent member of our Body "to be beyond calculation."

No locality in the Metropolis unites so many elements of convenience for such a concentration as Burlington House. If, to the application of other Scientific Societies than the three now there located, the reply should be given "that the State is not called upon to provide room for individuals who may choose to combine for the enjoyment of a special intellectual pursuit," we may rejoin that such Associations seek no selfish profit, but impart the results of their combined labour freely for the public weal. We might urge that the small amount of support needed for the enterprises and establishment of Science,—scarce equal to the product of the tax upon discovery and invention paid under the existing 'Patent Laws'—would be a good investment on the part of a Nation; and that, viewing such establishments and the prosecution of abstract physical truth in regard only to their material results, these might assure a Minister disposed to invest in what might seem to him the Lottery of Science, that the prizes are neither few nor small,—nay, some are incalculably great.

It now only remains for me to express how deeply I feel the honour conferred on me by the position in which, through your kindness, I am now placed; how highly I esteem the opportunity afforded me of addressing so distinguished and influential an audience in this most noble Hall; and how sincerely I thank you for the patience and favour with which you have received this Address.

REPORTS

ON

THE STATE OF SCIENCE.

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The present, Fourth, and probably last Report on Earthquakes that I shall have the honour of presenting to the British Association, has for its objects the discussion of the great catalogue of earthquakes printed in several preceding volumes of its 'Transactions,' the last portion of which only appeared in type in 1855, and the completion, as far as possible, of the complement of the other desiderata mentioned at the conclusion of the First Report (1850). The pressure of other occupations, with some uncontrollable circumstances, have delayed for nearly three years its appearance: the delay, however, has not been without advantage; it has enabled me more fully to grasp additional conditions and difficulties, before unnoticed, of some branches of the subject, and to derive advantage from the contemporaneous labours of the few physicists who are engaged in Seismology; foremost amongst whom stands M. Perrey of Dijon.

The reader will with advantage refer to the conclusions of the Second Report (1851), as to the construction of the catalogue which constitutes the Third (1854), before perusing the present; as well as to the concluding note of that Report, in which it is stated that the catalogue commencing at 1606 B.C., and originally proposed to be extended in its tabular form to the end of 1850 A.D., was concluded at the end of the year 1842, from which period up to 1850, and indeed later still, the catalogues of Prof. Perrey supply all that is needful, though it is to be regretted that they are not tabulated for more convenient reference. But although the British Association *Catalogue* concludes with 1842, the *discussion of facts* has been extended to the end of 1850, the base of induction for the last eight years being supported by the labours of Perrey.

The whole base of induction therefore for such conclusions as are here to be attempted,—embracing between 6000 and 7000 separate recorded earthquakes over every known part of the globe, both on land and ocean,—the character of the facts given,—their scantiness as to information of scientific value,—the methods, or rather the want of all method, in their observation, and other causes, mentioned in the Seeond Report,—I think justify me in stating my conviction, that nearly all that can be drawn from the collection and discussion of such records has now been done, and that the labour of collecting and calculating further and future *Seismologues* will be in a great degree thrown away, unless the cultivators of science of all countries,—in conjunction with the scientific bodies and the scientific departments of the chief civilized governments of the world,—shall unite in agreeing to some one uniform system of seismic observation, and record and transmit the results periodically to a central *bureau* for discussion. What has been done for astronomy and for terrestrial magnetism, is beginning to be done for meteorology, and through the suggestive labours of Maury, Bache, and others, for maritime discovery, ought to be done now for seismology, whose chief requirements could be readily added to those already supposed to be systematized from Lieut. Maury's proposals, as well as to those long in course in the astronomical, magnetic, and meteorological observatories of the world. The spread of the net of telegraphic wires rapidly over the whole earth offers facilities for the observation of earthquake phenomena, in which time always enters as so important an element, never before possessed. We shall revert to this in treating of seismometry.

Before proceeding to the discussion of the British Association Catalogue, I propose giving some account, in a connected form, of the discussions by Professor Perrey, of his own local or partial catalogues, and of the conclusions he has thence drawn; as well as referring to some minor catalogues, more or less completely discussed by their authors: amongst the latter, Mr. Milne's valuable contributions escaped my notice when preparing my first report. Perrey's labours in generalizing (as far, perhaps, as can from the data be safely done) the facts of several great seismic kingdoms, and announcing their results, form a valuable prelude to the still larger base of generalization finally here discussed, and extending to the whole known globe. The *discussed* catalogue memoirs of Perrey, to which I have had access, apply to the following localities:—

In the European Hemisphere—
- The Scandinavian Peninsula and Iceland.
- The British Islands.
- The Spanish Peninsula.
- France, Belgium, and Holland.
- The Basin of the Rhone.
- The Basin of the Rhine.
- The Basin of the Danube.
- The Italian Peninsula.
- Algeria and Northern Africa.
- The Turco-Hellenic Peninsula, with Syria.

And in the American Hemisphere—
- The Basin of the Atlantic.
- Canada and the United States.
- Mexico and Central America.
- The Antilles.
- Chili and La Plata.
- Cuba, by M. Poey.

In addition to which, Perrey has combined and discussed together—
- Europe, with the adjacent regions of Africa and of Asia.
- The North of Europe and of Asia—

viewing the three continents in the light of two parallel Austral and Boreal zones.

The general method adopted by Perrey has been, after an introductory physico-geographical sketch of the region, and the catalogue itself of earthquakes, to discuss them numerically and graphically.

In time { Numerically and relatively .... { By centuries
By years .. { Seasons, months, days.

Occasionally also with reference to lunations.

In space	With reference to direction, *i.e.* horizontal direction, of shock.	With reference to supposed derivative or mean horizontal direction of shock.

And lastly, as to relative intensity, or dynamic value of the shock in each direction, which he arrives at on the assumption that this, in any given rhumb, is proportional to the *number* of shocks observed in its direction in a given period, a supposition which—although perhaps not without some value, as admitting of one mode of regarding the relations of distant seismic regions not otherwise possible—admits of the gravest doubt whether it have any real natural basis.

We shall consider the results in the order above. Near as Norway and Sweden are topographically to the British Islands, it is not with these, but with Iceland and the intervening band of the Northern Ocean that the Scandinavian peninsula is in connexion as a seismic region; very few examples occur of simultaneous action between the former; but seldom has there been any marked convulsion in Iceland without commotion in Norway, &c., and *vice versâ*. Scandinavia itself, one of the most remarkable masses of land in slow process of elevation in the world, also shows its connexion with internal action; and were it not that Iceland is pierced with numberless vents, broken and shattered in every direction by volcanic action, that admits of no cessation or consolidation above, there can be no doubt that the destructive power of earthquakes would be manifested in the northern peninsula to a far more serious extent and intensity.

That Greenland, at least the east coast, and the Faröe Islands are shaken frequently, is highly probable, though I am not aware of any such record.

The following is the result of Perrey's chronology of this region:—

TABLE I.—Earthquakes of Scandinavian Peninsula and Iceland.

Century A.D.	With dates of month or day.												Of Season.		Of Year	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Winter.	Summer.		
XII. to XVII.	3	2	1	1	2	...	...	...	...	...	...	...	...	...	19	28
XVIII.	13	7	9	5	7	4	9	5	8	7	8	11	2	3	13	111
XIX.	17	11	11	7	7	6	8	8	10	10	11	6	...	1	...	113
Totals	33	20	21	13	16	10	17	13	18	17	19	17	2	4	32	252
	Winter 74			Spring 39			Summer 48			Autumn 53						

On examining this Table, Perrey remarks the same preponderance of earthquakes in the winter half of the year, that is evident from many of his other calculations for various regions. Here, for the six months of winter, there are 129 shocks, and but 91 for the summer half year.

Perrey is also of opinion, from the general result of his researches, that there is a preponderance of shocks at the equinoxes and summer solstice, which he denominates the "Critical Epochs" of the year. It is so for Scandinavia.

The total number of earthquakes given with dates is 252, representing by twelve the mean annual number. He tabulates the proportional number for each month thus:—

TABLE II.—Scandinavia. Relative frequency throughout the year.

January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Propor-tional number.
1·85	1·12	1·18	0·75	0·90	0·56	0·95	0·75	1·01	0·95	1·06	0·95	=12

Winter	1·38
Spring	0·73
Summer	0·90
Autumn	0·99

And at the two months of each solstice and equinox—

March and April	0·94
June and July	0·74
September and October	0·95
December and January	1·36

As to general direction of the *observed or horizontal element* of shock—it has in most instances traversed a line, with more or less divergence, stretching away from Iceland; and there can be little doubt that this is the real line of propagation of the original pulses.

Perrey, however, conceives that a mean or chief resultant direction of shock for each given seismic region may be calculated in the following way. Taking the mean frequency of shock =1, he finds for the eight principal rhumbs proportional numbers, as for example in the present case:—

TABLE III.

Rhumb, or direction of shock.	Relative frequency in direction.
N. to S.	0·73
N.E. „ S.W.	1·09
E. „ W.	0·73
S.E. „ N.W.	1·09
S. „ N.	1·09
S.W. „ N.E.	1·45
W. „ E.	1·09
N.W. „ S.E.	0·73

Then, considering the cause of movement in any given direction to be proportional in intensity to the number of times that it has acted in each observed direction, viz. as proportional to the preceding numbers, he treats these as the forces themselves given in magnitude and in direction, and compounds them for a single resultant according to Lambert's formula.

This process gives for Scandinavia a general resultant direction of propagation of S. 22° 30′ W., and with an intensity or force represented by 0·94.

If we study this presumed direction with the Mercator chart before us, we find that the line is not very wide of that forming the general length of the great Scandinavian chain, and is in fact nearly a normal to the actually observed directions of shock.

It is a fact observed in many other seismic mountain chains, as well as along the lines of great valleys and river-courses, that the main directions of propagation of shock are along the lengths of the chains, valleys or river-courses; and a very obvious explanation why this should *frequently* be the case suggests itself, namely, that the solid materials of the earth are less shattered and discontinuous, and more homogeneous in these directions than in those transverse to the ranges and valleys, &c.; but how far this is in any way connected in nature with Perrey's conclusion admits still of doubt; and indeed it is manifest that any attempt to calculate a general or mean resultant, from the horizontal component of shock *only*, must be at least incomplete, and, from other reasons that will be given when treating of seismometric instruments, may be said to be at present impossible. I should by no means wish, however, altogether to reject this ingenious method of discussion in the present state of our knowledge.

Perrey's results are subjoined for—

TABLE IV.—Earthquakes of the British Islands and Northern Isles.

Cent.	Earthquakes with date of month.												With date of Year only.	Total.
	Janua.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.		
XI.	...	...	2	2	1	...	...	1	...	...	1	...	1	8
XII.	1	...	...	1	...	...	...	1	2	...	...	2	4	11
XIII.	2	1	...	...	1	1	...	...	1	...	...	2	6	15
XIV.	...	...	...	...	1	...	1	...	...	...	1	...	1	4
XV.	...	...	...	...	...	...	...	...	1	...	...	...	...	1
XVI.	1	2	...	1	2	...	...	1	...	...	...	1	...	8
XVII.	3	...	...	...	...	1	...	...	2	3	1	2	2	14
XVIII.	5	4	7	5	3	2	3	5	6	6	8	8	1	63
XIX.	9	9	10	7	8	6	5	11	12	8	11	12	2	110
Totals.	21	16	19	16	16	10	9	19	24	17	22	28	17	234
	Winter 56			Spring 42			Summer 52			Autumn 67				

The number occurring in spring and summer together is but three-fourths that of autumn and winter united, the relative number for the four seasons being—

Winter .... 1·03
Spring .... 0·76
Summer .... 0·96
Autumn .... 1·24

And the two months of the critical epochs—

Winter solstice .... 1·28
Spring equinox.................. 0·96
Summer solstice .... 0·53
Autumnal equinox .... 1·13

The relative numbers as to horizontal direction :—

S.	to	N.	0·48
N.E.	„	S.W.	0·48
E.	„	W.	1·70
S.E.	„	N.W.	0·73
S.	„	N.	0·73
S.W.	„	N.E.	1·46
W.	„	E.	1·46
N.W.	„	S.E.	0·97

from which, by the preceding method, Perrey computes a mean horizontal direction of

S. 39° 5′ W. to N. 39° 5′ E.,

which is about the line of direction of Loch Ness and of the Caledonian Canal.

This is certainly, however, not the general or mean horizontal direction of British earthquakes, which appears to be one from south to north, veering more or less to the east or west, but having on the whole a direction passing through the probable focus of the Lisbon earthquakes and of the Canary Islands. I am not aware that any attempt has been made to ascertain the angle of emergence of the wave of shock for any British station, except indirectly by myself, in my "Memoir on the British Earthquake of November 1852" (Trans. Roy. Irish Acad. vol. xxii. part 1) at Dublin, which was from 25° to 30° inclined to the horizon; and assuming the origin to have been even somewhere *between* Great Britain and Lisbon, the depth of focus must have been very great; that earthquake extended over the greater portion of the British Islands, the maximum disturbance on the surface being about Shropshire.

Mr. David Milne, in one of a series of very able papers on British earthquakes in the 'Edinburgh Philosophical Journal,' vols. xxxi.–xxxvi., which I regret not having noticed in my Second Report as prominently as they deserve, expresses his conviction (as it appears to me, however, from very insufficient grounds) that all British earthquakes have had an origin of disturbance immediately beneath Great Britain, and not at some distant point beyond, his chief reasons being, 1, that with few exceptions they affected only certain portions of the island; 2, that there was in all the districts affected some spot where the concussion and attendant noise were greater than anywhere else, and that they diminished with their distance from this spot; 3, that the shock and the noise moved simultaneously from this spot.

A reference to the Catalogue will show that these are by no means the general prevailing facts; and if they had been so, they do not prove the point, for reasons to be gathered from the Second Report. In the absence of any knowledge of the angle of emergence, it is a very incomplete statement of fact when Milne says, that "out of 110 shocks recorded in England, 31 *originated* in Wales, 31 along the south coast of England, 14 on the borders of Yorkshire and Derbyshire, and 5 or 6 in Cumberland." "These facts," he adds, "seem to show that the seat of action cannot be very far down in the earth's interior." Locally variable surface-disturbance, and even none at certain localities, within large areas exposed to seismic action, are amongst the most common phenomena of observed earthquakes even of the greatest extent and intensity, and arise, amongst other reasons, from the heterogeneous and dislocated materials of the earth's crust perturbing the elastic wave. A considerable number of shocks, recorded in Scotland, have been stated to have had a horizontal direction more or less from west to east; and this is by no means incompatible with the general prevalent direction from south to north already mentioned; nor has it been unnoticed elsewhere, that long ranges of hills of hard elastic rocks, with deep intervening valleys, change the general horizontal course of the wave of shock reaching their flanks into one mainly felt along the line of the chain. The little shocks for long periods almost continuously felt in and about Comrie in Scotland, have all had a general direction from west to east; but these, like the similar phenomena long carefully observed by Prof. Merian at Basle in Switzerland, those at East Haddam in Massachusetts and elsewhere, I omit from consideration here, as very doubtfully belonging to the class of earthquakes proper at all, and perhaps no more than tremors, more or less forcible at the surface, due to the fracturing of rocky masses below, by the gradual processes of elevation or depression of the land. Excluding these, our records, so far as they go, point to the south-to-north general direction as given.

Milne has discussed, with reference to period of the year, the circumstances of 139 Scottish and 116 English earthquakes; and the result squares pretty closely with Perrey's.

The following is Milne's Table:—

TABLE V.

	Scotland.	England.	Total.	
January	14	11		
February	14	13	74.	Winter months.
March	12	10		
April	9	10		
May	8	4	44.	Spring months.
June	4	9		
July	5	5		
August	12	9	58.	Summer months.
September	12	15		
October	14	11		
November	20	12	79.	Autumn months.
December	15	7		
	139	116		

He notices also the fact, which we shall find has not escaped Perrey ('Memoir on France'), that the period of the year at which seismic action appears to be greatest, is that when both the actual height of the barometric column is the minimum, and the range of its oscillations the greatest in the year; and he has put with clearness the enormous total effect in the increase or diminution of pressure over large areas, due to such changes in atmospheric pressure, as a possible (he deems a certainly) connected cause in the production of earthquakes.

Proceeding now to the Spanish Peninsula, comprehending all west of the Pyrenees and the ocean washing the shores of Portugal, the following are Perrey's results:—

TABLE VI.—Earthquakes of the Spanish Peninsula.

Century.	Earthquakes with date of day or month.												With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.		
XI. ...	...	...	...	...	...	...	...	...	...	...	...	...	3	3
XII. ...	1	1	...	1	...	...	...	...	...	...	...	...	1	4
XIII....	...	...	...	...	...	...	...	...	...	...	1	...	2	3
XIV....	1	...	3	...	1	...	...	...	...	...	...	...	3	8
XV. ...	...	...	...	1	...	...	...	...	...	...	...	...	3	4
XVI....	2	...	...	1	...	...	3	...	...	1	...	...	3	10
XVII...	...	...	...	...	...	2	...	2	1	2	1	1	1	10
XVIII.	11	8	7	8	4	6	5	9	2	9	13	8	3	93
XIX....	10	5	6	7	4	6	10	5	9	11	7	5	...	85
Total.	25	14	16	18	9	14	18	16	12	23	22	14	19	220
	Winter 55			Spring 41			Summer 46			Autumn 59				

Taking the mean monthly frequency =1, the relative monthly frequency, and that according to season, are as follows:—

January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1·49	0·84	0·95	1·07	0·54	0·84	1·07	0·95	0·71	1·37	1·31	0·84
Winter 1·09			Spring 0·82			Summer 0·91			Autumn 1·17		

or in autumn and winter together, 114 earthquakes against 87 in the spring and summer.

As respects observed horizontal directions, the ratios were—

N.	to	S.	....	0·38
N.E.	„	S.W.	....	0·76
E.	„	W.	....	2·67
S.E.	„	N.W.	....	0·76
S.	„	N.	....	1·91
S.W.	„	N.E.	....	0·38
W.	„	E.	....	0·76
N.W.	„	S.E.	....	0·38

which, by the method of calculation already given as adopted by Perrey, gives for the mean horizontal direction—

E. 31° 56′ S. to W. 31° 56′ N.

This deduction appears to agree tolerably well with the actually recorded directions of shocks in Portugal and Spain, whose focus seems to be beneath the sea, between Lisbon and the Azores, all of which, as well perhaps as the Canaries, are connected as one seismic region. Perrey states, that in the Pyrenean chain, taken *separately*, not only is the preponderance of seismic action in the winter reversed, so that shocks are more frequent in summer than in winter, and those in summer and spring together are to those in autumn and winter as 2 to 3, but the observed horizontal direction is different, being most usual in the main line of the chain.

If this be so, it would either be explicable as a case of deflected wave, like that already mentioned with regard to the general north and south line in Great Britain, becoming a south-west and north-east one in Scotland, the angle of deflection in the present instance being small; or it would indicate that some of the shocks of the Pyrenees have connexion with the Mediterranean seismic region.

Spain, including Portugal, in its external configuration, with its vast table-land of the two Castiles, rising nearly 2000 feet above the sea, is perhaps the most interesting portion of Europe, not only in this respect, but as a region of earthquake disturbance, where the energy and destroying power of this agency have been more than once displayed upon the most tremendous scale.

It may be worth while to place here the tables of the progression of the shocks of the two great Lisbon earthquakes of 1755 and 1761, as collected by Milne (Edinburgh Phil. Journ. vol. xxxi.) from various sources, although the chief result has been already discussed in the Second Report. The time given in the Tables is reduced to Lisbon time; the distances in degrees of seventy miles English each.

Progressive rate of the shock, Lisbon earthquake of 1st November, 1755.

Localities.	Moment observed of shock.		Distance from presumed origin.		Time from impulse to arrival.		Observations.
	h	m	°	′	m	s	
Presumed focus, lat. 30°, long. 11° W.	9	23	...		...		At sea.
A ship at sea, in lat. 38°, long. 10° 47′ W.	9	24	0	30	1	0	
Colares	9	30	1	30	7	0	Portugal.
Lisbon	9	32	1	30	9	0	
Oporto	9	38	2	30	15	0	
Ayamonte	9	50	4	0	27	0	Spain.
Cadiz	9	48	5	0	25	0	
Tangier and Tetuan	9	46	5	30	23	0	
Madrid	9	43	6	0	20	0	
Gibraltar	9	55	6	0	32	0	
Funchal	10	1	8	30	38	0	Madeira.
Portsmouth	10	3	12	30	40	0	
Havre	10	23	13	0	60	0	
Reading	10	27	13	30	64	0	
Yarmouth	10	42	15	0	79	0	
Eyam Edge	10	30	15	30	67	0	Derbyshire (not certain.)
Durham	9	58	17	0	35	0	Uncertain.
Amsterdam	10	6	17	0	43	0	
Loch Ness	10	42	18	0	79	0	
Hamburgh	11	43	20	0	140	0	Uncertain.

Much uncertainty attends many of the statements as to time; and at several localities there is evidence that the shocks arrived much more rapidly than at others, in relation to distance. Thus at Cork two shocks were felt at $9^h 33^m$.

The longitudes are from the meridian of Greenwich.

Progressive rate of the shock, Lisbon earthquake of 31st March, 1761.

Locality.	Moment observed of shock.	Distance from presumed origin.	Time from impulse to arrival.	Observations.
	h m	° ′	m s	
Presumed focus, lat. 43°, long. 11° W.	11 51	...	...	At sea.
Ship at sea, in lat. 43°, not many leagues from coast of Portugal	11 52	0 30	1 0	
Ship in lat. 44°, and about 80 leagues off coast	11 54	1 45	3 0	
Corunna	11 51	2 30	6 0	
Ship lat. 44° 8′, and 80 leagues W.N.W. of Cape Finisterre	11 58	3 30	7 0	
Lisbon	noon	4 30	9 0	
Madeira	12 6	10 0	15 0	
Cork	12 11	9 30	20 0	
Loch Ness, between	11 40 and 12 40	11 0	20 0 and 49 0	Uncertain.
Amsterdam, between	1 15 and 1 45	15 15	84 0 and 114 0	Uncertain.

The great sea-wave of the shock of 1755 appears, from the recorded periods of arrival, to have travelled from its point of origin to the following places at the rates given in miles English per minute, according to Milne; assuming the transit rate uniform for the whole range of translation, which, however, is not possible:—

Plymouth	2·1	miles per minute.
Kinsale	2·7	,,
Mount's Bay	2·7	,,
Cadiz	3·6	,,
Funchal	3·7	,,
Ayamento	5·0	,,
Lisbon	5·5	,,
Antigua	6·0	,,
Barbadoes	7·3	,,

and that of the shock of 1761, as follows:—

Scilly Isles and Mount's Bay	2·0	miles per minute.
Dublin	2·1	,,
Kinsale	2·7	,,
Barbadoes	7·4	,,

I place these results of Milne's discussions of the imperfect materials at his command, rather for convenience of reference to future investigators, than as attaching much value to them beyond rude and provisional approximations*.

* For the same reasons I transcribe the following notice, which has appeared while these sheets have been printing:—

"Direction and velocity of the earthquake in California of the 8th and 9th January 1857. By Dr. John B. Trask." Silliman's Journal, Jan. 1858, vol. xxv. p. 146.

"The precise time of one of the shocks was obtained with tolerable accuracy for five

We proceed now to France, Belgium, and Holland, the limits of which Perrey fixes somewhat arbitrarily, as bounded on the south by the Mediterranean and by Spain, on the west and north by the Atlantic and Northern Oceans, as far as the Zuyder Zee, on the east by the Rhine and Alps, but comprising within it Geneva, in the basin of the Rhone, and Basle, Manheim, Frankfort-on-the-Main, and some other cities close to the right bank and in the basin of the Rhine.

TABLE VII.—Earthquakes of France, Belgium, and Holland.

Century.	Earthquakes with date of Day or Month.												With date of Season only.		With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Winter and Autumn.	Spring and Summer.		
IV.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
V.	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	1
VI.	...	...	...	1	...	1	...	...	...	...	...	1	...	...	3	6
VII.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
VIII.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
IX.	4	2	1	2	...	...	...	...	3	1	...	4	3	...	1	21
X.	1	...	...	...	...	...	...	...	...	...	...	...	...	...	1	2
XI.	...	1	2	...	2	...	2	...	1	3	2	1	...	...	2	16
XII.	3	...	1	2	2	1	...	1	...	...	...	1	...	...	1	12
XIII.	1	1	1	...	...	1	1	...	1	...	...	1	...	...	2	9
XIV.	1	1	1	1	2	1	1	...	2	1	2	1	1	1	6	21
XV.	...	1	...	2	...	1	1	2	1	...	3	1	...	1	1	14
XVI.	7	6	5	4	5	2	3	2	6	4	2	5	3	...	7	61
XVII.	13	15	4	4	7	3	7	3	8	4	6	11	...	...	6	91
XVIII.	26	20	17	26	11	18	17	15	13	18	23	28	1	...	4	237
XIX.	27	17	21	13	13	8	15	17	15	17	21	25	1	...	1	211
Total.	83	64	53	55	42	36	47	40	50	48	60	78	9	2	35	702
	Winter 200.			Spring 133.			Summer 137.			Autumn 186.						

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localities eastward of San Francisco, the greatest error in time of the clocks being 3′ 4″, and the least 0′ 22″. The time, being all reduced to that of San Francisco, gives the following results:—

Locality.	Lat.		Long.		Time of shock.			Elapsed time.		Velocity per min.
	°	′	°	′	h.	m.	s.	m.	s.	miles.
San Francisco	37	48	122	25	8	13	30	0	00	0·0
Sacramento	38	32	121	23	8	20	00	7	30	6·6
Stockton	37	52	121	34	8	23	00	9	30	6·5
Tejon	35	00	118	46	8	45	00	32	30	6·0
San Diego	32	42	117	13	8	50	00	36	30	7·0

or, for the average of the five observations, 6·2 miles per minute, or 545·6 feet per second. The author says, this closely approximates to Prof. Bache's results as to the rate of the earthquake at Limoda on 23rd December 1854 (Amer. Ass. for Advancement of Science, for that year); but he appears here to confound rate of sea-wave with that of earth-wave or shock."

And for the two months at each critical period of the year—

Dec. and Jan.,	Winter Solstice	161
June and July,	Summer ditto	83
March and April,	Spring Equinox..............	108
Sept. and Oct.,	Autumnal ditto	98

As respects horizontal direction, the relative numbers are,—

N.	to	S.	1·50
N.E.	„	S.W.	0·43
E.	„	W.	1·88
S.E.	„	N.W.	0·59
S.	„	N.	1·02
S.W.	„	N.E.	0·96
W.	„	E.	0·91
N.W.	„	S.E	0.69

which, by Perrey's method of calculation, gives for the mean general horizontal direction,—

N. 71° 27′ E. to S. 71° 27′ W.

To this he not only, in the case of France, confesses that he does not attach much weight, but also states that each century will not give the same mean resultant.

The actually observed districts of shock have been mainly along the lines of the valleys of the Rhine and Rhone, and in an inferior degree along those of the Loire, Seine, Garonne, and Meuse (the Pyrenees being viewed as part of the Spanish region), the tendency being to a direction in length of the valley, others across these. When the physical and geological features of France and the Rhine basin are recalled, it can scarcely be doubted that they constitute a natural independent seismic region, with centres of disturbance connected probably at great depths with the extinct volcanic countries of central France and of the Rhine. The almost continual slight disturbances of St. Maurienne, lasting for more than fifteen months at one time, appear quite analogous to those of Comrie and East Haddam. For the specialities of these and other questions of the French system, however, the memoir itself of Perrey must be consulted.

The basin of the Rhone has been consigned to a separate memoir. The precise limits assigned to the district are not stated; but we must assume them to extend somewhat vaguely beyond the actual catchment of the river. The results are given in

Table VIII.—Earthquakes of the Basin of the Rhone.

Century.	Earthquakes with date of Day or Month.												With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.		
XVI.	1	...	1	...	2	1	...	...	3	...	...	1	1	10
XVII.......	6	3	1	1	3	3	...	1	6	1	...	2	2	29
XVIII. ...	7	5	6	6	3	5	7	4	4	8	6	7	3	71
XIX.	12	12	8	3	3	2	2	4	6	6	8	14	1	81
Total ...	26	20	16	10	11	11	9	9	19	15	14	24	7	191
	Winter 62			Spring 32			Summer 37			Autumn 53				

presenting considerable similarity to the results for France as a whole. The following are the proportional numbers for the months:—

January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	ecember.
1·69	1·31	1·06	0·66	0·71	0·71	0·59	0·59	1·24	0·98	0·92	1·57

Or, for Winter .... 1·35
„ Spring.................. 0·69
„ Summer .... 0·81
„ Autumn .... 1·16

and for the two months each of

Winter Solstice .... 1·53
Spring Equinox .... 0·81
Summer Solstice................ 0·61
Autumn Equinox .... 1·05

and as to direction, following his usual method, Perrey arrives at a mean general horizontal resultant,—

S. 9° 44′ W. to N. 9° 44′ E.

This is not far from the general line of the course of the Lower Rhone; but Perrey remarks that numerous examples occur of shocks whose alleged horizontal movements were orthogonal to the river-valley, and to the meridian.

We pass on to the basin of the Rhine, which, in its entire extent, comprehends, in fact, a large portion of Switzerland, but whose precise limits Perrey does not define.

TABLE IX.—Earthquakes of the Basin of the Rhine and Switzerland.

Century.	Earthquakes with date of Day or Month.												With date of Season only.		With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Autumn and Winter.	Spring and Summer.		
IX.	3	2	1	2	...	1	...	...	1	1	...	5	1	...	2	19
X.	...	...	...	1	...	...	...	...	...	...	...	...	...	...	1	2
XI.	...	2	1	...	2	...	...	...	...	1	...	1	...	...	2	9
XII.	2	...	...	...	...	1	...	...	...	...	...	...	...	...	5	8
XIII.	1	...	...	...	...	...	...	...	...	...	...	...	...	1	1	3
XIV.	1	1	3	1	3	2	1	...	2	1	1	...	1	...	1	18
XV.........	...	1	1	1	1	1	1	1	...	...	3	2	...	...	...	12
XVI.	4	5	4	5	3	2	2	2	6	3	5	6	...	...	5	52
XVII.......	21	14	11	6	10	5	8	6	9	4	8	12	...	...	6	120
XVIII. ...	15	12	10	9	6	12	11	10	8	9	17	20	...	...	2	141
XIX.	15	17	13	12	11	6	12	11	10	17	24	25	...	...	...	173
Total...	62	54	44	37	36	30	35	30	36	36	58	71	2	1	25	557
	Winter 160			Spring 103			Summer 101			Autumn 165						

The autumn and winter together here present a number, having nearly the same ratio to that of spring and summer together, as 3 : 2.

And at the critical periods of the year, of two months each, we have

Winter Solstice	133
Spring Equinox	81
Summer Solstice	65
Autumnal Equinox	72

while, as respects horizontal direction,

S. to N.	0·78
N.E „ S.W.	0·44
E. „ W.	1·33
S.E. „ N.W.	0·89
S. „ N.	2·00
S.W. „ N.E.	1·11
W. „ E.	0·78
N.W. „ S.E.	0·67

and, by calculations on before-given principles, a mean general horizontal direction of

S. 7° 9′ E. to N. 7° 9′ W.

which corresponds pretty well with the general direction of the river valley. Observation, however, indicates, in most of the localities upon its banks, frequent and wide occasional departures from such direction; and, indeed, in the broken country forming a large portion of its length it is improbable it should be otherwise.

The basin of the Danube.—This vast tract of country has been left very ill-defined as to its limits by Perrey, as respects the subject of his research. His catalogue shows that he does not limit himself precisely to the catchment of this mightiest of European rivers, but, in fact, includes something like the whole of that vast tract of country between a line on the north, reaching from Prague to Kherson; and on the south, from Venice to Constantinople, and even occasionally stretching beyond these limits.

Table X.—Earthquakes of the Basin of the Danube.

Century.	Earthquakes with date of Day or Month.												With date of Season only.		With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Winter and Autumn.	Spring and Summer.		
V. to XV...	1	1	...	...	2	1	1	1	1	...	...	...	...	...	11	19
XVI.	3	1	...	...	3	4	1	1	3	...	1	1	1	...	16	35
XVII.......	2	4	1	...	...	1	2	3	...	...	2	5	...	...	11	31
XVIII. ...	11	10	4	8	8	5	6	9	1	7	5	8	2	...	4	88
XIX.	14	15	9	8	12	8	16	11	11	16	10	12	1	1	1	145
Total ...	31	31	14	16	23	19	26	25	16	23	18	26	4	1	43	318
	Winter 76			Spring 60			Summer 67			Autumn 67						

Perrey remarks, that although the total number of shocks recorded appears great, it is very small in proportion to the enormous area embraced—nearly ten times that of the basin of the Rhone; and he justly concludes, that, were it not for the penury of records in those regions, so much of which is semibarbarous or thinly inhabited, the total number in it would be far greater than he gives. While the general character of shocks here is not that of great intensity, instances are to be found of some, of disastrous power. The relative numbers are for

Winter Solstice	1·33
Spring Equinox	0·70
Summer Solstice	1·05
Autumnal Equinox	0·91

and as respects horizontal direction, the results are,—

N.	to S.	1·33
N.E.	„ S.W.	0·50
E.	„ W.	1·33
S.E.	„ N.W.	0·50
S.	„ N.	1·17
S.W.	„ N.E.	1·00
W.	„ E.	1·33
N.W.	„ S.E.	0·85

from which Perrey obtains a mean general horizontal direction of

W. 2° 39′ N. to E. 2° 39′ S.

This is again very much the line of the Lower Danube itself, which, however, over so vast an area, and fed by vast rivers poured into it on the northern side between great flanking ranges passing more or less north and south, can in reality exercise little or no influence; and too much stress must not be laid upon any observation as to line of *direction*, even when the azimuth surface may be reliable. This applies to every earthquake country; uninstructed observers are very liable to mistake the direction of movement, by confounding the direct effects of the shock with those due to inertia of bodies moved. In the Danube basin, it must at present remain undecided whereabouts the centre or centres of disturbance proper to the region are to be found. On the north, the Carpathians probably are above the centre for those whose horizontal direction is more or less north and south; but whether the shocks from east to west, and veering towards the north or occasionally to the south, have their origin in the Caucasus, or beneath the eastern extremity of the Euxine, or are also in connexion with the great seismic energies that so powerfully and frequently display themselves in Syria and the south-east, indeed all over Asia Minor, yet requires to be investigated.

In the region of the Italian Peninsula, Perrey includes the whole of Italy and the mass of the Alps, exclusive of Savoy (which is included in the basin of the Rhone), with Sicily, Malta, Sardinia, &c., reaching into the centre of the Mediterranean Sea; and, on the north, all the localities whose watersheds are not into the Rhone, Rhine, or Danube. For the conventional limits which Perrey has fixed for himself in deciding upon the *isolation* in point of time of each distinct earthquake, often in this region continuing for many days with little interruption, the memoir itself must be consulted.

Table XI.—Earthquakes of the Italian Peninsula, with Sicily, Sardinia, and Malta.

Century.	Earthquakes with date of Day or Month.												With date of Season only.		With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Autumn and Winter.	Spring and Summer.		
IV.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6	6
V.	...	...	...	...	...	...	...	...	...	...	...	...	1	...	4	5
VI.	...	...	...	...	...	...	...	...	...	1	...	1	...	...	1	3
VII.	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1
VIII.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	2
IX.	...	...	...	1	...	1	...	...	...	...	...	1	...	...	3	6
X.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	3
XI.	1	1	1	1	...	...	...	...	...	...	...	...	...	...	3	7
XII.	2	1	...	...	...	...	...	...	...	1	...	1	1	...	12	18
XIII.	1	...	...	2	1	...	...	...	1	...	1	1	...	...	8	15
XIV.	3	1	...	...	1	1	...	...	3	...	2	3	...	...	6	20
XV.	...	1	1	...	1	...	...	1	...	1	...	6	...	...	7	18
XVI.	2	...	1	1	3	1	1	1	2	...	2	2	1	...	15	32
XVII.	10	15	14	15	4	13	8	7	10	4	6	3	2	1	9	121
XVIII.	45	41	43	29	38	46	21	31	24	44	31	30	2	1	12	438
XIX.	37	39	38	35	32	24	33	36	23	41	22	29	...	...	1	390
Total ...	101	99	98	84	80	86	63	77	63	92	64	77	7	2	92	1085
	Winter 298			Spring 250			Summer 203			Autumn 233						

M. Perrey, having obtained access to the work of Muratori and other documents, produced a supplement to this memoir, the result of which he has given in

Supplemental Table XII.—Italian Peninsula, Sicily, Sardinia, and Malta.

Century.	Earthquakes with date of Day or Month.												With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.		
VIII.	...	...	...	...	...	...	...	...	...	...	...	...	1	1
IX.	...	...	...	...	...	...	...	...	...	...	...	...	...	...
X.	...	...	...	...	...	...	...	...	...	...	...	...	3	3
XI.	...	...	...	1	...	...	...	...	2	...	...	...	2	5
XII.	4	...	...	1	2	1	...	1	...	1	...	...	12	22
XIII.	2	...	...	2	1	1	2	1	...	2	3	1	11	26
XIV.	5	5	6	2	4	2	4	1	6	3	1	6	6	51
XV.	5	2	4	2	3	3	1	10	5	1	4	5	2	47
XVI.	1	...	...	1	1	1	...	...	...	...	...	...	1	5
XVII.	...	...	2	4	...	...	1	...	1	1	...	...	...	9
XVIII.	1	1	1	2	1	3	2	2	1	4	1	...	1	20
XIX.	7	5	10	8	8	10	8	10	4	4	4	10	...	88
Total ...	25	13	23	23	20	21	18	25	19	16	13	22	39	277
	Winter 61			Spring 64			Summer 62			Autumn 51				

In the first of these, the winter and spring earthquakes together are to the summer and autumn together

as 6 : 5.

In the supplemental table taken alone, however, the winter season has lost its preponderance, and autumn shows the smallest number.

The number in winter and autumn together, however, still slightly exceeds that for spring and summer, in the ratio of 9 : 8.

While this shows the usual doubtfulness of generalizations from partial data, the result rather tends to awaken increased attention to the very prevalent excess of seismic action in the winter half-year, shown by so many catalogues, and here sustained, though by a supplement, that, taken alone, somewhat departs from the principle.

As regards direction, he finds

N.	to S.	0·82
N.E.	„ S.W.	1·08
E.	„ W.	1·94
S.E.	„ N.W.	1·29
S.	„ N.	1·29
S.W.	„ N.E.	0·40
W.	„ E.	0·91
N.W.	„ S.E.	0·28

and the mean general horizontal direction of resultant

S. 72° 27′ E. to N. 72° 27′ W.

Observation by no means accords with any such general mean direction. It has repeatedly indicated movements in Italy and Sicily in every azimuth—perhaps with some greater prevalence of those from north to south, and the reverse; but the fact appears to be that these regions have their centre of disturbance almost directly beneath, and hence, as is the case in South America, and the Moluccas, Philippines and Sunda Islands, the emergence of the wave generally makes an extremely large angle with the horizon; and the horizontal component is ill-suited to easy observation. The most fearful earthquakes with which this region has been visited, and whose force has reached France, Germany, Holland, and England, and into Africa, are said to have had a point within their immediate ciucture where the shock was absolutely vertical, as in the Riobambe earthquake recorded by Humboldt.

The memoir of Perrey on Algiers and Northern Africa is brief; and he laments that the want of information, and of access to sources of it not attainable, prevented his collecting a sufficient number to found any generalization upon. The following results alone he is able to tabulate:—

TABLE XIII.—Earthquakes of Algeria and Northern Africa.

Earthquakes with date of Month.												With date of Year only.	Total.
January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.		
5	2	6	7	3	2	2	5	1	4	8	1	17	63
Winter 13			Spring 12			Summer 8			Autumn 13				

The want of further historic information upon this region is much to be regretted. It has been, since anything has been recorded of it, known as subject to earthquakes. Cities, the sites of bishoprics in the ancient Christian church of Africa, were thus demolished, and now astonish the traveller amidst rocky solitudes by acres of hewn stone on the sites of prostrate edifices that mark the past magnificence of Carthaginian and Roman rule. And at the present day, earthquakes are frequent and serious, as the many edifices erected by the French since they have been in possession of Algeria, and since thrown down, demonstrate.

Whether, as a seismic region, Northern Africa have a centre of disturbance of its own, and if so, whether this exists deep within the little-known recesses of the Atlas chain, or beneath the southern verge of the Mediterranean basin, or whether its disturbances are only derivative, and have their centre either in the volcanic region of the Canaries or amongst the towering peaks of Abyssinia, all yet remains to be discovered. No information worthy of any confidence has reached me as to the general horizontal direction of shocks in this region. How much to be desired is it, that the government of the Emperor of the French would systematize seismoscopic observations in their African possessions!

The last of Perrey's European series now comes before us; and in the following table he has given the results for—

TABLE XIV.—Earthquakes of the Turco-Hellenic Territory, Syria, the Ægæan Islands, and Levant.

Century.	Earthquakes with date of Day or Month.												With date of Season only.		With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Autumn and Winter.	Spring and Summer.		
IV.	...	...	...	...	...	...	1	1	...	1	...	1	8	1	15	23
V.	1	...	1	3	...	1	...	...	3	...	1	...	...	...	9	19
VI.	1	1	...	1	1	...	2	2	2	3	2	2	...	...	10	27
VII.	...	...	...	1	...	1	...	...	...	...	...	...	...	...	6	8
VIII.	2	2	1	1	1	...	...	...	...	1	...	...	...	1	8	12
IX.	1	...	...	...	1	...	...	2	...	...	...	...	1	...	2	7
X.	...	...	...	...	...	...	...	...	2	2	1	...	...	...	...	5
XI.	1	2	1	...	...	1	...	1	1	...	1	3	...	...	7	18
XII.	...	...	...	...	1	1	...	...	...	...	...	2	...	...	19	23
XIII.	...	...	1	...	1	1	...	...	...	...	...	1	...	...	9	13
XIV.	...	1	1	...	...	...	...	2	...	...	...	...	...	1	3	8
XV.	...	...	...	1	...	...	...	...	1	1	1	...	...	...	7	11
XVI.	...	...	2	...	2	1	...	...	1	...	1	1	...	...	14	22
XVII.	3	1	3	4	4	1	6	2	5	1	5	1	...	...	17	53
XVIII.	9	8	5	9	10	13	12	8	11	8	9	8	2	...	12	124
XIX.	22	20	16	10	16	15	14	22	14	17	12	14	2	2	1	197
Total	40	35	31	30	37	35	35	40	40	34	33	33	8	5	134	570
	Winter 106			Spring 102			Summer 115			Autumn 100						

This vast region embraces the Turco-Greek peninsula, from Trieste to Constantinople southward of the Balkan range, the Greek Archipelago and Asia Minor to Bagdad, with a portion of Syria and the Levant.

Perrey remarks, that the number of facts he has been able to collect are fewer than the known seismic character of the region warrants, and rightly attributes this to want of record, and to the want of communication in these parts of the world. He also remarks (what has been pointed out in the Second Report as applying to Antioch, &c.) that here seismic energy appears to have been in various localities extremely paroxysmal in its action, with long periods of intermediate cessation. In the Turco-Greek peninsula, earthquakes have long been both frequent and formidable.

For the four critical periods of the year he finds

Winter Solstice	73
Spring Equinox..................	61
Summer Solstice	70
Autumnal Equinox	74

Pouqueville ('Voyage en Grèce') has given some very singular facts and speculations as to the time of year of earthquakes in Epirus, &c., in relation to the rains. They need inquiry and confirmation.

In analysing the horizontal direction of shock, Perrey has deemed it proper to separate the region under three sub-districts, in consequence of the broken character of the Greek peninsula, and the very diverse *orientation* of the coasts, river-courses, and mountain-ranges throughout all its parts.

Directions.	Adriatic. Trieste to Zanté.	Constantinople.	Smyrna.	Total.
N. to S. ...	4	2	2	9*
N.E. to S.W. ...	...	...	...	...
E. to W. ...	2	...	...	3†
S.E. to N.W. ...	1	...	...	1
S. to N. ...	4	1	1	6
S.W. to N.E. ...	1	...	...	1
W. to E. ...	3	...	...	3
N.W. to S.E. ...	2	1	1	5‡

These figures are meagre enough. By the usual method, Perrey calculates a mean general horizontal direction of shock,

N. 34° 37′ W. to S. 34° 37′ E.

The deduction, however, is plainly in this instance of little value. Many shocks in this region have been described as approximating to vertical; and this is to be anticipated from one having a centre of disturbance almost in its midst with active volcanic action. All its eastern end, Syria, &c., however, has some separate centre of disturbance, either in connexion with the eastern chains of Asia Minor, which appear to abound in igneous formations or with the Southern Arabian centre; while Constantinople, the Dardanelles, and the western and southern shores of the Euxine may also be in connexion with the Caucasian centre of action.

We have now completed Perrey's European series. He passes to the American by the discussion of the basin of the Atlantic, viewed as comprehending all from Iceland on the north to Tristan d'Acunha on the south, and on the east and west everything between the shores of the continents of the New and Old Worlds.

Within this oceanic expanse no less than five great and probably connected centres of volcanic action exist: Iceland, the Azores, the Canaries,

* Including once for Aleppo. † Including once for Latakia.
‡ Including once for Thassis.

the Cape de Verds, the West India Islands, and the great submarine volcanic region first noticed by M. Daussy, besides many other points, as Ascension, St. Helena, St. Paul's, &c., at which extinct volcanic phenomena are visible. The number of observations, however, as yet recorded of earthquake-shocks within the basin is so very small, that Perrey has been only able to collect from 130 to 140 instances between the years 1430 and 1847, or about three a year on the average; so that he does not deem the basis large enough to warrant any numerical discussion. The observations of M. Daussy, "Sur l'existence probable d'un volcan sousmarin situé par environ 0° 20' de lat. S. et 22° 0' de lon. ouest," published in vol. vi. p. 512, 'Comptes Rendus de l'Académie' (1853), have, however, made this one of the most interesting seismic regions on the globe.

M. Moreau de Jonnès ('Comptes Rendus,' vol. vi. p. 302) has given two recorded observations on board French ships, the 'Cæsar' and the 'Sylphide,' which render the existence of a submarine volcanic tract on the bank of Bahama highly probable; but M. Daussy has collected and given observations of shocks received by vessels at sea at various periods, but all within a given limited area, which renders the existence almost certain of a vast active volcanic suboceanic area in the basin of the Atlantic, nearly midway between Cape Palmas on the west coast of Africa, and Cape St. Roque on the east coast of South America, or in the narrowest part of the ocean between these continents. This vast disturbed and perhaps partially igneous ocean-floor can be no less than nine degrees in length from west to east, and from three to four degrees in breadth from north to south. The following are the observations given by Daussy; and the relative positions of the several recording ships are given in the diagram (fig. A.):—

17th Oct. 1747.—The ship 'Le Prince,' Bobriant: two shocks. Lat. 1° 35' S.; long. 20° 10' W.

5th Feb. 1754.—The ship 'Silhouette,' Pintaul: one shock, with trembling. Lat. 0° 20' S.; long. 23° 10' W.

13th April 1758.—The frigate 'Fidèle,' Lehoux: several shocks. Lat. 0° 20' S.; long. 23° 10' W.

3rd May 1761.—The ship 'Le Vaillant,' Bouvet: saw an islet of sand above water, in lat. 0° 23' S. and long. 21° 30' W.

3rd Oct. 1771.—The frigate 'Le Pacifique,' Bonfil: one shock and trembling. Lat. 0° 42' S., and long. by estimation, 22° 47' W. An agitated sea, and no bottom found on sounding.

19th May 1806.—M. de Krusenstern (ship's name not given). Lat. 2° 43' S., and long. 22° 55' W. Saw columns of smoke twelve or fifteen miles to the N.N.W., which he and Dr. Horner attributed to volcanic submarine eruption.

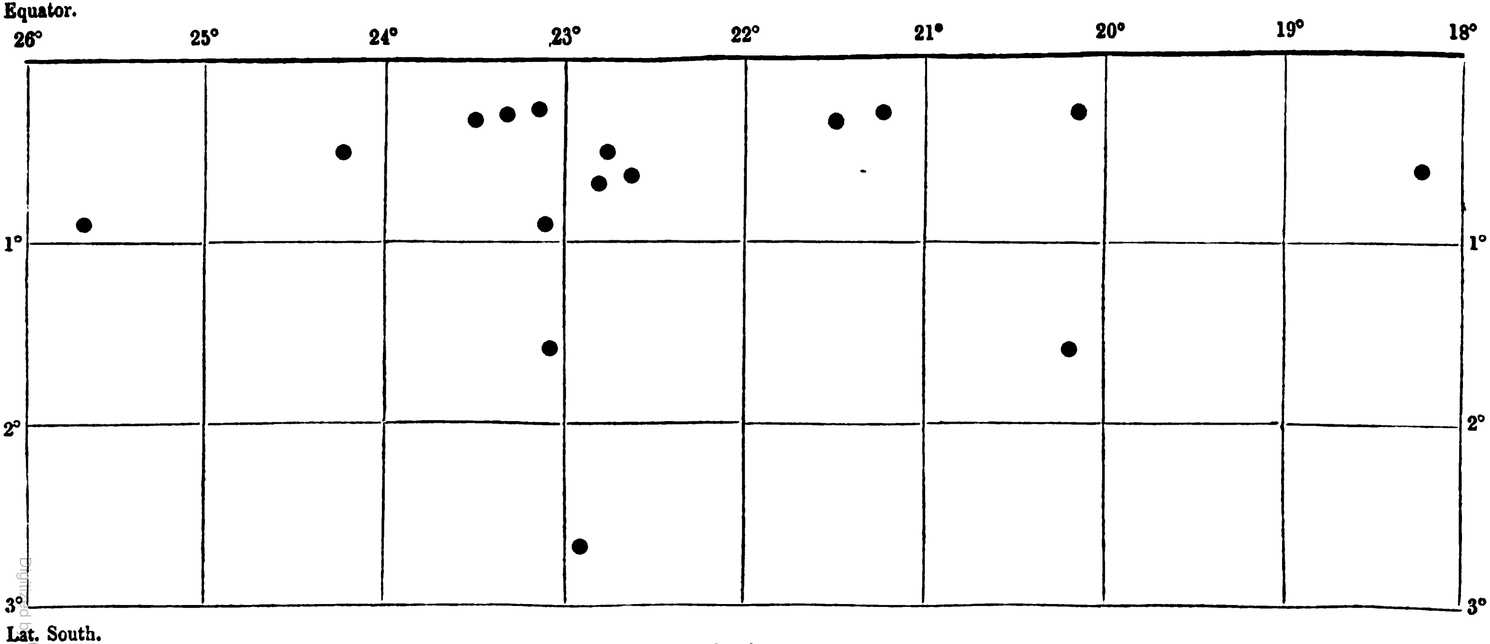
18th Dec. 1816.—The ship 'The Triton,' Proudfoot: in lat. 0° 23' S., and long. 20° 6' W., passed over a shoal of about three miles from east to west, and one mile from north to south. Twenty-six fathoms water, with bottom of brown sand.

12th April 1831.—The ship 'Eagle,' J. Taylor: in lat. 0° 22' S., and long. 23° 27' W., the sea being perfectly calm; one violent shock: the rudder was powerfully shaken, and a muffled sound was heard from beneath.

—— Nov. 1832.—The ship 'La Seine,' Le Maire: in lat. 0° 22' S., and long. 21° 15' W. Under easy sail; one powerful shock.

9th Feb. 1835.—The barque 'The Crown,' of Liverpool (captain's name not given): lat. 0° 57' S., and long. 25° 39' W. When going six knots, was thought suddenly to have struck on a coral rock and to have

Fig. A.



Daussy's submarine volcanic region of the Atlantic.
Places at which the shocks have been felt. Long. W. from Paris.

grated over it; but on sounding directly after, found 135 fathoms water.

28th Jan. 1836.—The ship 'Philantrope de Bordeaux,' Jayer: in lat. 0° 40′ S., and long. 22° 30′ W. Violent shock and trembling for three minutes.

13th & 16th March 1836.—The American ship 'St. Paul,' of Salem (captain's name not given), being ten miles to the west of the 'Philantrope,' perceived the same shock.

—— in 1836 Captain Fergusson, of the ship 'Henry Tanner,' presented to the Royal Asiatic Society of Bengal, through F. L. Huntley, Esq., volcanic ashes or cinders, like black pumice, which he had found on the surface of the sea when much agitated, in lat. 0° 35′ S. and long. 18° 10′ W.

—— In a previous voyage Captain Fergusson, in lat. 1° 35′ S. and long. 23° 5′ W., was alarmed by a violent shock, accompanied by a great noise, as if he had struck upon a rock, but could find no bottom on sounding.

Some other instances are said to be found in the 'Sailing Instructions for the Azores' by Tofino, translated by M. Urvoi de Portzampare, in the 'Annales Maritimes de France,' which I have not been able to consult. We possess enough, however, to indicate that a submarine volcanic tract is in activity beneath the Atlantic, as large in area as Great Britain, and that the bottom of the ocean there is rendered uneven in the extreme, immense protrusions taking place in deep water. How desirable would it be that some British ships were commissioned to examine this tract more perfectly, especially to obtain accurate soundings and sectional lines of the bottom from east to west and from north to south, and, if possible, to obtain, by dredging or otherwise, good specimens of the material of the bottom, and also observations of the temperature of the sea at various depths!

Our knowledge of the distinguishing marks of suboceanic and subaerial volcanic ejecta, of the chemical reactions producing mineral species, under the conditions (so vaguely understood as yet) of high temperature and great pressure in presence of water, might receive important accessions, if such specimens from the bottom could be obtained from thence (or from other similar positions), while our ideas of the extent to which local ocean currents may be produced and maintained by the local heating of the deep sea immediately above such volcanic tracts might be enlarged, and other trains of future research suggested.

Above all, how forcibly does the existence (so far almost unnoticed and unknown) of this vast volcanic and seismic submarine region indicate the desirableness of having henceforth a well-arranged system of scientific observation and mode of daily entry in the log-book made part of the duties of ships of every civilized maritime nation, and having such entries referred to a special office (with us, probably, in connexion with the Admiralty or with a revivified Board of Longitude) for extract, record, and discussion! That certain classes of observations could not be made on board our ships at present, although the zeal of our officers of the navy and of some of the mercantile marine might be counted on, is certain; but it is equally so that very many of the highest value to cosmical science could be made and recorded, if the system were once arranged, the classes of observation determined on, properly ruled and arranged log-books prepared, and the making certain observations (to be determined on by the central board beforehand in each instance) made matter of duty. Navigation and commerce would gain, eventually, quite as much as, by the small sacrifice of time and labour, they thus gave to science. I venture respectfully to commend it to our own, to the American, and to all European governments.

In his memoir on the Earthquakes of the United States and Canada, Perrey may be said to include the whole northern continent of America, with the exception of Mexico and Central America, to which he has devoted another memoir.

The two following tables, XV. and XVI., give the results of his discussion:—

Table XV.—Earthquakes of the United States and of Canada.

Century.	Earthquakes with date of Day or Month.												With date of Year only.	Total.
	January.	February.	March.	Ap. 1.	May.	June.	July.	August.	September.	October.	November.	December.		
XVII.......	3	1	...	...	...	1	...	...	...	1	...	...	4	10
XVIII. ...	7	9	9	3	3	3	6	8	5	7	12	12	6	88
XIX.	4	4	3	3	3	...	4	6	3	2	7	5	5	51
Total ...	14	14	12	6	6	4	10	14	8	10	19	17	15	149
	Winter 40			Spring 16			Summer 32			Autumn 46				

Here the number of earthquakes in autumn and winter are to those of summer and spring as 88 to 49, or nearly as 2 to 1; and for Perrey's critical periods:—

Winter solstice....................	31
Spring equinox....................	18
Summer solstice	14
Autumnal equinox	18

Perrey wholly disputes the verity of Humboldt's conclusion ('Cosmos,' t. i. p. 519, trad. p. M. Fays) that earthquakes are most frequent at the equinoxes, and declares that the results of all his memoirs prove the contrary.

He discusses from his catalogue the relative number of shocks in each State of the Union; but this is comparatively of less importance to science than to social life. He has not been able to ascertain the northern limit of seismic action, but sees ground to believe it has reached Greenland more than once, but that frequent shocks pass no further north than the Canadas.

The only records with direction of motion given are twelve in number, viz.,—

N.W. to S.E......................	6
W. „ E.	3
N.E. „ S.W.......................	2
E. „ W.	1

and calculating, upon his already known method, the mean direction from this narrow base, he finds it

N. 31° 54′ W., to S. 31° 54′ E.;

but he confesses his own opinion, derived from a broad view of all the facts and the topographic character of the country, to be, that the prevailing direction is from north to south, or the contrary.

The vertical component of motion has only been given in one instance here; but there is every reason to presume that the angle of emergence of the seismic wave all over the northern continent of America is steep.

TABLE XVI.—Earthquakes of Mexico and Central America.

Century.	Earthquakes with date of Day or Month.												With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.		
XVI.	...	...	...	...	...	...	...	...	...	...	1	...	5	6
XVII.	...	1	2	...	...	...	...	...	...	1	...	...	3	7
XVIII. ...	...	2	4	3	...	3	2	1	3	...	...	...	6	24
XIX.	3	2	2	2	6	2	2	1	1	3	2	3	1	30
Total. ...	3	5	8	5	6	5	4	2	4	4	3	3	15	67
	Winter 16			Spring 16			Summer 10			Autumn 10				

The steep emergence of the wave is most remarkable in Mexico, where, at Acapulco, it is frequently felt as a directly vertical pulse from beneath (as at Riobamba).

Perrey does not attempt, from his materials, a full discussion of the horizontal component of motion. The prevailing impression in Mexico is that the direction of shock is parallel to the chain of the Cordilleras. Some, however, of the most remarkable shocks have apparently moved at right angles to the preceding.

The truth is, in a wide region situated close to, and no doubt in great part close *above*, vast centres of disturbance, whose pulses reach the surface generally with large angles to the horizon, there must be horizontal components in every azimuth, and only distinguishable in one more than another, as the accidents of the originating blows, of the heterogeneous formations through which they are transmitted, and the opportunities of exactness of observation, &c. vary.

Perrey concludes this memoir with a *résumé* of the labours of Arago, Von Buch and Berghaus, on the volcanoes of Mexico and the Andes.

In his memoir on the Antilles, Perrey includes Cuba, which has also been the subject of research to M. Poey, now stationed at the Observatory of Havanna—with Hispaniola, Jamaica and Porto Rico in the greater, and in the lesser isles Antigua, Barbadoes, St. Christopher's, Guadaloupe, Martinique, Granada, Trinidad, St. Thomas, Santa Cruz, Dominica, St. Vincent, Tobago, and St. Lucia, &c. In discussing the copious materials at his disposal in this vast region, Perrey has found it necessary to adopt certain conventional licences with reference to some of the very prolonged earthquakes, whose slight but continuous shocks have often (as at Comrie and East Haddam) lasted for a great length of time, reckoning each month of such shocks as equivalent to one great earthquake.

In the following table, XVII., he has given the distribution in time:—

TABLE XVII.—Earthquakes of the Antilles.

Century.	Earthquakes with date of Day or Month.												With Season only.		With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Winter and Autumn.	Spring and Summer.		
XVI.	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	1
XVII.	...	1	1	1	1	1	1	...	...	...	...	...	...	...	10	16
XVIII. ...	6	7	3	4	3	5	10	7	9	10	5	3	...	...	13	85
XIX.	9	8	19	12	12	10	9	16	12	10	13	12	1	...	2	145
Total ...	15	16	23	17	16	16	20	23	22	20	18	15	1	...	25	247
	Winter 54			Spring 49			Summer 65			Autumn 53						

Contrary to the result usual for Europe, the number of shocks in summer here seems to preponderate; and in the critical periods we have—

Winter solstice	30
Spring equinox	40
Summer solstice	36
Autumnal equinox	42

or for autumn and winter together 108; spring and summer 114,—a result equally contrary to what has been found so uniformly for Europe, and to the prevalent belief of the inhabitants of the islands themselves, who deem the equinoxes the dangerous times.

Representing by unity the mean degree of frequency, and by 12 the whole number of earthquakes given with date of month, we find for each month the following proportional number:—

January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
0·81	0·87	1·25	0·92	0·87	0·87	1·09	1·25	1·19	1·09	0·98	0·81
0·98			0·89			1·18			0·96		

As regards horizontal direction of shock, his data give—

E.	to	W.	9
S.	„	N.	5
N.	„	S.	3
W.	„	E.	2
N.E.	„	S.W.	2

from which, by his usual method, he deduces a mean horizontal direction—

E. 22° 5′ S. to W. 22° 5′ N.;

and it is worthy of remark, that Deville gives, as greatly disturbed in 1843, the zone running parallel to the great circle of W. 35° N. to E. 35° S., or E. 35° S. to W. 35° N., which is about parallel also to Perrey's mean direction. It must not be forgotten, however, that, in 1812 and in 1843, shocks were observed at right angles to this, and in some cases, as in 1770, in all azimuths; and also that the prevalent opinion of the inhabitants of the West Indian Islands is, that they have a general north and south horizontal direction, thus coming within the scope of the general direction of similar phenomena on the northern and southern continents of America.

M. Poey, of the Observatory, Havanna, has published, in the 'Nouvelles Annales des Voyages' for 1855, a memoir and supplement upon the earthquakes of Cuba, separately, with copies of which he has obligingly furnished me. It would be out of place in this Report to discuss M. Poey's views as to the connexion between cyclones, or other storms, and earthquakes, or as to the physical causes of the impulse producing shocks. As regards the first, it may, however, be remarked in passing, that violent and sudden local change of barometer-pressure must (as I have indicated in a former report) be viewed as a *possible inducer* of such reactions beneath the surface as may possibly result in earthquakes; and that as respects the part which water, under heat and pressure, may play in its spheroidal state, I have also indicated fully as much as the present state of our knowledge will sustain. As respects the statistic results of M. Poey's labours, they are embraced in the following table, which combines the facts of both memoir and supplement:—

TABLE XVIII.—Earthquakes of Cuba.

Century.	Earthquakes with date of Day or of Month.												With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.		
XVI.	...	...	...	...	...	...	...	...	...	...	...	...	4	4
XVII.......	...	4	...	...	...	...	...	...	...	...	...	...	...	4
XVIII. ...	...	...	...	...	...	...	...	...	...	...	...	...	2	2
XIX.	4	3	2	3	3	4	5	2	6	5	6	4	3	50
Total ...	4	7	2	3	3	4	5	2	6	5	6	4	9	60
	Winter 13			Spring 10			Summer 13			Autumn 15				

Cuba, therefore, appears to show 28 earthquakes in the winter and autumn, and 23 only in the summer and spring.

The surface of this single island is, however, perhaps too small to attach much importance to its isolated discussion*.

The last of Perrey's monographic memoirs is that on Chili and La Plata,

* While this Report has been passing through the press, I have received from M. Poey a copy of his later and more elaborate "Chronological Catalogue of Earthquakes in the West Indies, from 1530 to 1857, extracted from 'l'Annuaire de la Société Météorologique de France,' tom. v. p. 75, Séance du 25 Mai, 1857," and regret that the limits of a foot-note preclude the possibility of analysis of his valuable memoir.

Of a total of 690 earthquakes, he finds that 142 occurred in winter, 156 in spring, 187 in summer, and 154 in autumn,—thus so far corroborating Perrey's result deduced from a smaller base.

A very complete Seismic Bibliography for the Antilles concludes M. Poey's memoir.

or the region lying between the western slope of the Andes and the sea, from the 25° to the 45° south latitude, between the Desert of Atacama on the north, and the Archipelago of Chonos on the south.

The following table contains his numerical results for a region, however, in which shocks of greater or less intensity are almost of daily occurrence:—

TABLE XIX.—Earthquakes of Chili and the basin of La Plata.

Century.	Earthquakes with date of Day or Month.												With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.		
XVI.	...	...	...	...	...	...	...	...	...	1	...	...	4	5
XVII.	...	1	1	...	1	...	...	...	...	...	...	...	6	9
XVIII. ...	1	1	1	...	1	1	...	1	...	...	...	1	8	10
XIX.	14	10	14	8	19	11	16	15	16	9	27	8	8	170
Total ...	15	12	16	8	21	12	16	16	16	10	27	9	16	194
	Winter 43			Spring 41			Summer 48			Autumn 46				

From this table he has omitted several earthquakes, whose period has been prolonged to several weeks or even months, by a convention like that adopted here with regard to the memoir of Comrie, &c.

A table of earthquakes noticed as occurring in Peru from A.D. 1810 to 1835, by M. Castelnau, was presented to the Academy of Sciences in 1847, by Arago ('Comptes Rendus,' 2 Nov. 1847); but the catalogue itself is not given, and I am not aware that it has appeared elsewhere.

M. Lambert, mining engineer of Chili, in a memoir on the causes of earthquakes in Chili and Peru ('Ann. de Chim. et de Phys.,' t. xlii. pp. 392–405), published in 1829, mentions that the Chilians vulgarly divide their year into three seasons or "temporadas," and that one of these, the first, composed of January, February, March, and April, is called "temporada de los tremblores," or earthquake season; on comparing the facts of his catalogue, with the popular belief however, Perrey finds the facts palpably contradict it.

As to the prevalent horizontal direction here, Perrey makes no attempt to discuss it, contenting himself with the remark, that the popular belief is universal in the region, that it follows the chain of the Cordillera. In a country, however, having so little of its *observed* surface (for the great sandy deserts are nearly unknown as respects our inquiry) of a level character, with a general seaward slope from the great central axis, and with the origin of disturbance so closely beneath, that many of the most formidable earthquakes have emerged almost vertically over considerable tracts, the attempt to fix a prevailing horizontal direction would be nugatory.

Finally, we come to the two last of Perrey's memoirs which have been referred to—those in which he has brought under one view many of the facts of his monographs, and graphically discussed the results in tables for all Europe, with the adjacent parts of Africa and of Asia, and for the north of Europe with the north of Asia, viewed as one great boreal band. The results of the former are given in the following Table:—

TABLE XX.—Résumé of the Earthquakes of Europe, and of the adjacent parts of Asia and of Africa, from A.D. 306 to 1843.

Century.	Earthquakes with date of Day or Month.												With date of Season only.		With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Winter and Autumn.	Spring and Summer.		
IV.	...	...	...	...	...	...	1	...	...	1	...	2	3	1	12	21
V.	1	...	...	3	...	2	1	...	2	...	2	...	3	...	11	25
VI.	...	1	...	2	2	1	2	1	2	3	2	3	1	...	11	31
VII.	...	...	...	1	...	1	...	2	...	...	...	...	...	...	6	10
VIII.	2	2	1	1	1	...	...	...	...	...	...	...	1	...	3	11
IX.	4	2	...	1	1	1	...	1	2	2	...	6	5	1	10	36
X.	1	...	1	1	...	...	...	...	1	2	1	1	1	...	8	17
XI.	1	4	5	1	2	1	2	2	4	3	3	3	1	...	19	51
XII.	8	2	2	3	3	2	...	3	3	...	1	4	3	...	34	68
XIII.	3	2	3	1	5	...	2	...	1	...	2	5	4	...	27	55
XIV.	1	1	3	...	3	4	3	2	4	3	4	4	2	2	22	58
XV.	...	1	1	1	2	2	2	2	1	2	2	7	...	1	17	41
XVI.	10	5	6	8	10	4	2	3	9	3	6	10	3	...	31	110
XVII.	21	16	15	13	6	9	10	3	14	3	10	17	1	1	41	180
XVIII. ...	77	53	45	52	36	49	49	49	32	62	55	62	14	4	21	660
XIX.	99	100	90	59	55	55	74	78	72	92	60	78	6	1	6	925
Total ...	228	189	172	147	126	131	148	147	147	176	148	202	48	11	279	2299
	Winter 589			Spring 404			Summer 442			Autumn 526						

Autumn and winter still preponderate thus for entire Europe. As regards the "critical periods" of the year, the results are—

	For XIX. Century.	For the whole period.
Winter solstice	177	253
Spring equinox	151	170
Summer solstice................	129	150
Autumnal equinox	164	159

and for the half year, and XIX. century only—

Autumn and Winter............	527
Spring and Summer	394

and for the whole period of nearly 15½ centuries—

Autumn and Winter	1165
Spring and Summer	857

or about as 1 : 0·75.

The mean *annual* number of earthquakes in Europe, &c., deduced from the data of the ten years between 1833–1842, while it was everywhere at peace, and intelligence well conveyed, Perrey finds to be nearly 33 per annum. He considers that one-fifth more may probably have occurred that have not come to his knowledge, so that the mean annual number would be 40, or between 4 and 5 per month.

The remainder of this memoir is occupied with remarks upon very numerous and interesting secondary phenomena, recorded of the earthquakes referred to in the catalogue discussed.

In the last memoir—that in which Perrey discusses the earthquakes of northern Europe and northern Asia together—he expresses with some caution his own belief that the preponderance of seismic phenomena in the winter half-year above the summer half, in the ratio above given, is worthy of acceptance as an empiric law for Europe at least, but doubts whether it may be extended to the other hemisphere.

The geographical limits of this seismic region are somewhat arbitrary, reaching from the Elbe on the west to the extremity of Kamtschatka on the east; bounded on the north, in Europe, by the Baltic and White Seas, but in Asia reaching to the Arctic shores; and on the south, in Europe, by a great circle passing north of the Carpathian Mountains to the Euxine, the Caucasus and the Caspian, and thence by the Desert of Gobi to the Sea of Okhotsk—a vast tract, containing many important mountain-chains, though principally distinguished, as Perrey remarks, by its immense plains and low table-lands.

The eight following tables give not only his numerical results for this region, but a general comparative view of the numerical results of nearly the whole of his memoirs, for which I have somewhat extended some of the tables, and changed their order slightly.

TABLE XXI.—Earthquakes of the Northern Zone of Europe.

Century.	Earthquakes with date of Day or Month.												Season only.		With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Winter and Autumn.	Spring and Summer.		
VIII. to XVI.	2	1	1	1	3	2	1	2	1	...	1	...	...	2	8	25
XVII.	3	5	...	1	...	...	...	1	1	...	2	2	...	...	4	19
XVIII	10	7	4	4	4	1	2	5	4	4	3	5	1	...	...	54
XIX.	12	5	4	5	6	3	2	4	2	9	7	6	...	...	...	65
Total ...	27	18	9	11	13	6	5	12	8	13	13	13	1	2	12	163
	Winter 54			Spring 30			Summer 25			Autumn 39						

TABLE XXII.—Earthquakes of the Northern Zone of Asia.

Century.	Earthquakes with date of Day or Month.												With Season only.		With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Winter and Autumn.	Spring and Summer.		
XVIII......	3	6	2	1	1	...	1	2	2	2	1	3	1	...	7	32
XIX.	4	6	6	4	4	3	5	7	6	3	4	5	...	...	...	57
Total ...	7	12	8	5	5	3	6	9	8	5	5	8	1	...	7	89
	Winter 27			Spring 13			Summer. 23			Autumn 18						

Table XXIII.—Earthquakes of the Northern Zone of Europe and of Asia together.

Century.	Earthquakes with date of Day or Month.												With Season only.		With date of Year only.	Total.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Winter and Autumn.	Spring and Summer.		
VIII. to XVI.	2	1	1	1	3	2	1	2	1	...	1	...	...	2	8	25
XVII.	3	5	...	1	1	...	...	1	1	...	2	2	...	...	4	20
XVIII.	13	13	6	5	5	1	3	7	6	6	4	8	2	...	7	86
XIX.	16	11	10	9	10	6	7	11	8	12	11	11	...	...	...	122
Total ...	34	30	17	16	19	9	11	21	16	18	18	21	2	2	19	253
	Winter 81			Spring 44			Summer 48			Autumn 57						

Table XXIV.—General Result as to Mensual Relative Frequency of Earthquakes.

Regions.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual ratio.
Europe (the whole)...	1·35	1·11	1·07	0·95	0·85	0·81	0·87	0·95	0·89	1·02	0·93	1·21	34·32
France and Belgium...	1·52	1·17	0·97	1·01	0·77	0·66	0·86	0·73	0·91	0·88	1·09	1·43	7·02
Italy and Savoy	1·16	1·13	1·27	1·05	0·96	0·96	0·94	0·94	0·76	1·13	0·76	0·94	10·83
Basin of the Rhone ...	1·69	1·31	1·06	0·66	0·71	0·71	0·59	0·59	1·24	0·98	0·92	1·57	1·91
Basin of the Danube..	1·38	1·38	0·62	0·71	1·11	0·84	1·16	1·11	0·71	1·02	0·80	1·16	3·18
Scandinavia	1·85	1·12	1·18	0·75	0·90	0·56	0·95	0·73	1·01	0·95	1·06	0·95	2·52
Europe, Northern Zone	2·19	1·46	0·73	0·89	1·05	0·49	0·43	0·98	0·66	1·05	1·05	1·05	1·63
Asia, Northern Zone...	1·04	1·78	1·19	0·74	0·74	0·44	0·89	1·33	1·19	0·74	0·74	1·19	·89
Both Zones united ...	1·78	1·57	0·89	0·84	0·94	0·47	0·58	1·10	0·84	0·94	0·94	1·10	2·52

Table XXV.—Result as to Relative Frequency in Season.

Region.	Winter.	Spring.	Summer.	Autumn.
Europe (the whole) ...	1·18	0·87	0·90	1·05
France and Belgium ...	1·22	0·81	0·83	1·13
Italy and Savoy.........	1·19	0·99	0·88	0·94
Basin of the Rhone ...	1·35	0·69	0·81	1·16
Basin of the Danube...	1·13	0·89	0·99	0·99
Scandinavia	1·38	0·73	0·90	0·99
Europe, Northern Zone	1·49	0·81	0·69	1·05
Asia, Northern Zone...	1·33	0·67	1·13	0·89
Both Zones united ...	1·41	0·75	0·84	0·99

TABLE XXVI.—Result as to Relative Frequency at the Equinoxes and Solstices.

Region.	Winter Solstice.	Spring Equinox.	Summer Solstice.	Autumnal Equinox.
Europe (the whole) ...	1·25	0·99	0·82	0·93
France and Belgium ...	1·43	0·96	0·73	0·87
Italy and Savoy.........	1·02	1·13	0·93	0·92
Basin of the Rhone ...	1·53	0·81	0·61	1·05
Basin of Danube	1·33	0·70	1·06	0·91
Scandinavia	1·36	0·94	0·74	0·95
Europe, Northern Zone	1·74	0·87	0·48	0·91
Asia, Northern Zone...	1·20	1·04	0·72	1·04
Both Zones united ...	1·48	0·96	0·58	0·98

TABLE XXVII.—Result as to Relative Directions of Horizontal Component of Shock.

Region.	N. to S.	N.E. to S.W.	E. to W.	S.E. to N.W.	S. to N.	S.W. to N.E.	W. to E.	N.W. to S.E.	Total.
Europe (the whole) ...	1·57	0·65	1·65	0·67	1·12	0·88	0·88	0·60	464
France and Belgium ...	1·50	0·43	1·88	0·59	1·02	0·96	0·91	0·69	149
Italy and Savoy.........	1·09	0·91	2·25	0·91	1·09	0·51	0·87	0·29	110
Basin of the Rhone ...	1·30	0·37	1·30	0·56	1·86	1·12	1·12	0·37	43
Basin of the Danube...	1·33	0·50	1·33	0·50	1·17	1·00	1·33	0·83	48
Scandinavia	0·73	1·09	0·73	1·09	1·09	1·45	1·09	0·73	22
Europe, Northern Zone	1·19	0·60	1·48	0·30	2·07	0·00	1·98	0·59	27
Asia, Northern Zone...	2·35	1·88	0·94	0·47	0·47	0·94	0·00	0·94	17
Both Zones united ...	1·64	1·09	1·27	0·36	0·45	0·36	1·09	0·73	44

TABLE XXVIII.—Result as to Comparative General Resultant Horizontal Direction and Intensity.

Region.	Resultant Horizontal Direction.	Intensity of Resultant.
Europe (the whole)	E. 33° 42′ N.	0·61
France and Belgium	N. 71° 27′ E.	0·56
Italy and Savoy	S. 85° 51′ E.	2·15
Basin of the Rhone	S. 9° 44′ W.	1·23
Basin of the Danube...............	W. 2° 39′ N.	0·66
Scandinavia	S. 22° 30′ W.	0·94
Europe, Northern Zone	S. 17° 45′ W.	0·23
Asia, Northern Zone...............	N. 23° 48′ E.	3·14
Both Zones united	N. 23° 55′ E.	1·06
British Islands	S. 39° 5′ W.	?
Spanish Peninsula..................	E. 31° 56′ S.	?
Basin of the Rhine	S. 7° 9′ E.	?
Turco-Hellenic Territory	N. 34° 37′ W.	?
Mexico and Central America ...	N. 31° 54′ W.	?
The Antilles	E. 22° 5′ S.	?

There remains to be noticed, of M. Perrey's labours, his discussion of the periodicity of the earthquakes of his annual catalogues for 1844, 1845, 1846, and 1847, with reference to the phases of the moon's motions, published in 'Mém. de l'Académie des Sciences de Dijon,' 1848, 1849, part. des Sciences, p. 105, &c., and also presented to the Institute of France at a later period.

The result he arrives at, as respects these four years, is, that the number of earthquakes occurring at the Perigees (when the tides are highest and lowest) are, to those occurring at the Apogees, as 47 : 39,—a conclusion which, independently of the assumptions by which it is arrived at, must be as yet accepted with caution upon so narrow a base of induction, although possessing more than enough probability, from physical considerations, to induce further inquiry.

The Academy of Sciences (Paris) appointed a commission to report upon M. Perrey's communication; and the following translation of its report ('Comptes Rendus,' tom. xxxviii. 12 Juin, 1854) will give a tolerably clear notion of his views, which here rest upon a larger base than in his Memoir as first published:—

"The Academy has commissioned us, MM. Liouville, Lamé, and myself, to draw up a report on a paper presented by M. Alexis Perrey, Professor in the Faculty of Sciences at Dijon, on the 21st March 1853, 'On the Connexion which may exist between the occurrence of Earthquakes and the Moon's Age,' and on a note also presented by him on the 2nd January last, 'On the occurrence of Earthquakes in connexion with the Moon's passing over the Meridian.'

"At the time of the presentation of the paper of March 1853, M. Arago had been appointed a member of the commission. The lamented death of our illustrious associate, since that date, left a vacant place in our commission; and before the presentation of the note of the 2nd January 1854, M. Lamé was appointed to it.

"M. Arago, whose attention nothing escaped which relates to the physics of the globe, pursued with sustained interest the researches of M. Alexis Perrey. The Academy has not forgotten the care which he constantly took to draw its attention to the notes which the learned Professor at Dijon addressed to him from time to time within the last few years, in consequence of the inquiries he was engaged in on the subject of earthquakes. M. Arago made particular mention, at several meetings, of the connexion which the author had already traced between the occurrence of earthquakes and the moon's age.

"The cause of the interest which belongs to this subject is easily explained. If, as is generally believed in the present day, the interior of the earth is, owing to its high temperature, in a liquid or melted state, and if the globe has but a comparatively thin solid crust, the interior, being deprived of solidity, is compelled to yield, like the superficial mass of the ocean waters, to the attractive force exercised by the sun and moon, and it acquires a tendency to swell out in the direction of the rays of these two bodies; but this tendency meets with a resistance in the rigidity of the solid crust, which occasions shocks and fractures of the latter. The intensity of this force varies, like the tides, according to the relative position of the sun and moon, and consequently according to the moon's age; and we must also observe that as the tides ebb and flow twice in the course of a lunar day, at those hours which agree with the passing of the moon over the meridian, so the direction of the attraction exercised upon a point of the interior globe must change twice a day, according as the point recedes or approaches the meridian, the plane of which passes through the centre of the moon. Without entering into longer details, we can easily conceive that, if the fusion of the interior mass of the globe plays a part among the causes of earthquakes, then its influence may become evident by a necessary connexion, capable of observation, between the occurrence of earthquakes and the circumstances which modify the moon's action upon the entire globe, or upon a portion of it, namely, its angular distance from the sun, its real distance from the earth, and its angular distance from the meridian of the place, or, in other words, the moon's age, the time of perihelion, and the hour of the lunar day.

"These considerations, which occurred to M. A. Perrey, doubtless inspired him with the idea of the two works which we have been commissioned to examine, at the same time that they assisted in attracting the interest of M. Arago and many other learned men to the results which he obtained; but they also suggest that the essential object of the inquiries on which we are commissioned to report ought to be, to ascertain the precise date, according to the lunar day and month, of every earthquake the record of which history has preserved, and even of each of the shocks of which these earthquakes consisted. We can easily imagine the immense toil which such a research would demand, and understand that M. Alexis Perrey having already devoted several years to it without bringing it to a termination, has yet been enabled at different intervals to obtain such partial results as M. Arago deemed worthy of the encouragement and attention of the Academy; and that the learned Professor at Dijon is impatient, before encountering the labours of still more years, to learn whether the Academy approves of the course which he has hitherto pursued. The necessity the author feels for the support and direction of the Academy explains why he has, upon several occasions, submitted to it results which naturally could not be complete, and which are not entirely so even in the paper and note which we are commissioned to examine. In the paper presented on the 21st March 1853, 'On the Connexion which may exist between the occurrence of Earthquakes and the Moon's Age,' the author has devoted the first chapter to the calculation and numerical changes of the rough results of observation.

"He has supposed four possible methods of calculation. In the first, already followed in the memoir presented to the Academy May 5, 1847, the author considers as a day of an earthquake each day upon which a shock has been felt, whether in a single country, or in two or more countries at the same or at different hours, separated from each other by spaces in which the motion was not experienced. Then noting, according to the knowledge of the period, to which day of lunation each day of earthquake corresponded, he arranges all the days which belong to the first day of lunation, then all those which correspond to the second day, the third, the fourth, &c.; and he constructs a table composed of thirty lines, each line indicating the number of earthquakes which belong to the corresponding day of lunation. Now these numbers vary one day with another, and they vary nearly in accordance with the same law, both in a table comprising a total of 2735 days of earthquake, the result of researches carried on during the years from 1801 to 1845, drawn up by the author and presented to the Academy May 5th, 1847; and in a new table containing a total of 5388 days of earthquake, embracing the result of extensive researches carried on from 1801 to 1850.

"In both tables the number of earthquakes corresponding to the days close to the Syzygies, is generally a little more considerable than that which corresponds with the days close to the Quadratures. In the second method of calculation, the author regards earthquakes experienced in different regions, separated by regions where the shock is not perceptible, as distinct one from the other, and reckons as an earthquake every percussion felt in a separated region. This new method of calculation increases the number of earthquakes in the 1st table from 2735 to 3041, and in the 2nd table from 5388 to 6596. The same law is again apparent in these two new tables, and also in the four other tables which the author forms by dividing the half century between 1800 and 1850 into two intervals, each of a quarter of a century, and by successively applying the first and second methods of calculation to the earthquakes of these two intervals.

"In the third method of computation, M. Alexis Perrey regards every shock of which an earthquake is composed as a distinct phenomenon, and registers it separately; but he does not possess the documents necessary for this plan, because the number of shocks in each earthquake has not been accurately noted. The author has hitherto contented himself with considering in this manner the Table of 931 shocks felt in South America, chiefly in Arequipa, published by M. Castelnau in the 5th volume of his 'Journey through the Central Regions of South America.' This table, without leading to results identical with those furnished by the other two methods, exhibits the fundamental relation already manifested. Lastly, in the fourth method of computation, the application of which would often be very difficult, and which has not yet been attempted by M. Alexis Perrey, we are to consider as an unique phenomenon the number of shocks consecutively felt in the same country during an interval preceded and followed in the same country by periods of tranquillity.

"To the nine tables formed by one or other of the three first methods of computation the author has added a tenth, formed by the first method. This only embraces four years, from 1841 to 1845, and contains but 422 days of earthquakes. In spite of this comparatively limited number, the proportion of the figures appears the same. In all these tables we observe a marked preponderance in the number of earthquakes which take place upon days close to the Syzygies, over those which occur at the Quadratures. However, it is but a general law which can be observed in the statement of figures of which the tables are composed; and there are numerous exceptions. In order to weaken the force of these anomalies, and more clearly to exhibit the fundamental law, M. Alexis Perrey divides the 29*j.* 53*i.* of which the lunation is composed, into 12ths, 16ths, 8ths,—and forms, by proportionate calculations applied to the ciphers of his different tables constructed on the solar days, the numbers which correspond to each fraction of lunation; he displays in all these new tables (excepting some anomalies of detail) the law of the predominance of earthquakes at the Syzygies, and thus confirms more and more his conclusion, that, for half a century, earthquakes have been more frequent at the Syzygies than at the Quadratures. M. Alexis Perrey has also studied, in the more or less extensive registers which assisted him to draw up his different Tables, the question, whether there exists any connexion between the occurrence of earthquakes and the variable distance of the moon from the earth in traversing the different portions of her elliptical orbit. For this purpose he has calculated in each of his registers, and according to the different modes of computation employed to draw up the above-mentioned tables, how often earthquakes have occurred two days before and after, and upon the day of the moon's perigee and apogee; and he has shown, in the numbers thus obtained, that the total corresponding to the perigee, in which the moon is nearest the earth, is greater than that corresponding to the apogee, in which she is at her greatest distance: then, in order to compare the results, he has taken the difference of the totals thus obtained and divided it by their sum, which has given him the quotients $\frac{1}{16\cdot5}$, $\frac{1}{23\cdot6}$, $\frac{1}{23\cdot5}$, $\frac{1}{34\cdot4}$, $\frac{1}{15\cdot6}$, $\frac{1}{21\cdot2}$, $\frac{1}{10\cdot75}$, which are all greater than $\frac{1}{30}$, and the last almost equal to $\frac{1}{10}$.

"The apparent result from this is, that the difference between the unequal attraction exercised by the moon at her greatest and nearest distance has a sensible influence over the occurrence of earthquakes. In the note on the 'occurrence of Earthquakes in connexion with the passing of the Moon over the Meridian,' which he presented to the Academy January 2, 1854, M. Alexis Perrey discusses the question, whether the division of the shocks of earthquake during a lunar day is, like the tides, connected with the passage of the moon over the superior and inferior meridian. For this method of investigation he could only avail himself of the 824 shocks felt at Arequipa, which are registered with day and hour in the above-mentioned table of M. de Castelnau. By means of proportional calculations, which must have occupied a considerable time, he has calculated to which hour after the passage of the moon over the meridian, each of these shocks corresponds. He thus formed a 1st table (which he afterwards changed by dividing it into sixteen equal portions, grouped side by side, to form eighths) containing the 24 hours 50 minutes and a half of which a lunar day generally consists.

"By these two methods (notwithstanding some marked anomalies which could not but exist in so limited a number of facts as 824), the results obtained in both arrangements manifest the existence, in the length of a lunar day, of two periods of *maximum* for the occurrence of shocks, and two of *minimum*. The two periods of maximum occur at the hours of the passing of the moon over the superior and inferior meridians; and the periods of minimum fall about the middle of the intervals.

"M. Alexis Perrey has thus succeeded, by the simple analysis of catalogues which he had previously drawn up, in proving, by three different and independent methods, the influence which the moon possesses in the production of earthquakes:—

"1st. That earthquakes occur more frequently at the Syzygies.

"2nd. That their frequency increases at the Perigee, and diminishes at the Apogee of the moon.

"3rd. That the shocks of earthquake are more frequent when the moon is near the meridian than when she is 90 degrees away from it.

"But the numerical tables from which these three propositions are derived, present some anomalies; and the author has omitted nothing to endeavour to account for them, and to prove the law which is revealed at their first inspection. He first conceived the idea of constructing graphically the numbers contained in the tables, so as to obtain by the usual method a polygonal line analogous to those by which barometrical observations are usually represented, in which the eye catches at once the general course of phenomena in the midst of anomalies which tend to conceal it. We are tempted to regret that he has not further developed this graphical part of his work, which would have had the great advantage of displaying at a glance the direct result of his researches; and that he has not even annexed to his memoir any of the lines which he constructed. But M. Alexis Perrey considered that he would obtain still more certain results by employing calculation; and to this arduous task he devoted the 2nd Chapter of his principal paper, and the Second Part of his note of the 2nd January, 1834. It would be difficult for us to follow the author step by step in these analytical discussions; we will restrict ourselves to the observation, that, in order to represent the result of his work, he has employed a formula of interpolation of this kind:—

"$\phi = M + A \sin(t+\alpha) + B \sin(2t+\beta) + C \sin(3t+\gamma) + \ldots$, in which M, A, B, C, &c. are always coefficients of the same nature as ϕ; α, β, γ, &c., are always angles, and t a variable angle dependent on the lunar motion, which will be equal to 0 degree for the new moon, to 90 degrees for the first quarter, to 180 degrees for the full moon, &c. He then adapts this formula to the numerical tables deduced from observation, and determines the particular truths which it contains. By means of the formula thus obtained, the author was enabled to draw up numerical tables corresponding to those deduced from observation alone, and in which the law of the phenomena appears disconnected from the principal anomalies which tended to obscure it in the first tables. The numbers contained in these new tables are carefully arranged, and form regular curved lines, in which the law is clearly manifest. These curves have a marked resemblance to each other, although they are not entirely alike—which could not be, for they are only approximative—and each bears the stamp of the group of figures which it represents. The resemblance of these curves is essentially increased by the fact that each presents two principal maxima corresponding to the Syzygies, and two principal minima corresponding to the Quadratures. We are thus brought back to the conclusion so evident by M. A. Perrey's toil,—that, for half a century, earthquakes have been more frequent at the Syzygies than at the Quadratures.

"The Academy fully conceives the importance of this conclusion, and appreciates the labour the author has taken to collect nearly 7000 observations on the first half of this century. This number, however, is very small for the solution of a question of this nature; and it is very desirable to have it increased, either by collecting all future observations from year to year, or by going back to past centuries, as the author has already commenced doing."

These views of Perrey have found support in the opinions enunciated by M. Zantedeschi as to the probable existence of a terrestrial as well as an oceanic tide, one in which the solid mass of the earth's crust, and the liquid or semiliquid nucleus beneath (if indeed it exist in any such state) is supposed to be an ellipsoid, with a major axis perpetually following the movements of the moon and sun. To what extent such a change of form is possible in the solid material of our planet under the constraint of the same forces that produce the oceanic tides (and whose elevations must in so far act against such change of form), it is for physical astronomy to determine. But even if its existence be admitted, and the change of level of a given point on the earth's surface were proved to amount to many feet—to far more, in fact, than the total elevation of the greatest ocean tide-wave, it is difficult to conceive how it even then could be a *direct or immediate* cause of earthquakes. Such change of form would be probably quite insignificant as compared with the earth's total mass; so that the flexures or changes of form produced by it in the solid crust would probably be far within the elastic limits of its materials, and, hence, the occurrence of fractures or dislocations due to such a train of causes impossible.

If it ultimately prove a fact that there is a real relation in epoch between earthquakes and the ocean tides, or the moon's and sun's position in respect to the earth, the phenomena will probably be found in relation, only through the intervention of changes in terrestrial temperature, or in the great circulations upon or within our planet, of its electrical, or magnetic, or thermic currents, or the conversion of these into each other reciprocally, and not to the direct action of the variable attractive forces of our primary and our satellite. To some such conversions of force into heat, developed at local foci, it would appear much more probable that all volcanic phenomena are due, than to a universal ocean of incandescent and molten lava beneath our feet, with a thin crust of solid matter covering it, the present or historical existence of which is not only not proven, but for which no argument of weighty probability has been, as I conceive, advanced.

In the present state of our knowledge of the obscure relations between the internal mass and actions of our planet with the cosmical forces that act upon it both within our own atmosphere and from the abysses of space beyond, and in our comparative ignorance even of the terrestrial phenomena themselves, no speculation, however hazardous or hardy, that is based upon a natural hypothesis, need be regretted: such views in the beginning of every separate road of inductive science are eminently suggestive, and, although in themselves false, may point towards truth. It is only in this aspect that a memoir by Dr. C. F. Winslow, M.D., 'On the Causes of Tides, Earthquakes, Rising of Continents, and Variations of Magnetic Force,' requires notice. The communication appears to have been made to the Academy of Sciences of San Francisco, California, by the author, in 1854 or 1855. I have met with it only through a printed copy, for which I believe I am indebted to the author.

That our satellite *does* actually influence the magnet *directly*, has been discovered by Herr Kreil, of the Vienna Royal Observatory (see 'Phil. Trans.,' 1857, and 'Proc. Roy. Soc.,' vol. vii. pp. 67–75). General Sabine, in the introduction to vol. iii. of 'Magnetic and Meteoric Observations made at Toronto,' p. 9, states—"The decennial solar period of ten or eleven years, in connexion with the solar spots, proved to connect itself with the magnetism of the earth, but *not* with other cosmical phenomena" (see 'Phil. Trans. 1852,' Art. VIII.); that is to say, I presume, not with such cosmical phenomena as have had their laws already ascertained. Again (p. xi.), the author adds—"The solar diurnal variation appears to be wholly irreconcilable with the hypothesis which attributes the magnetic variation to thermic causation."

We find, then, that both sun and moon influence, with other and more occult forces than those that address sense and eye, our planet, and that these all incessantly modify the conditions and relations (mutual and to things on the surface) of every grain of matter in the inmost recesses of its nucleus. While every cosmical force is thus, as soon as its laws are discovered, found to be correlated to every other, all mutually convertible, and capable of disappearing and reappearing "by measure, number, and weight," as mere brute power or mechanical force, it is not too much, at least, to affirm the advancing probability, that a distinctly (though irregularly) *periodic* phenomenon, such as earthquakes, will be found intimately related to them, possibly with no very long or intricate intermediate chain of causation.

As regards the periodicity, &c., of those solar spots which admit of consideration in relation to the two paroxysmal maxima and two minima in each century (noticed hereafter), Humboldt may be referred to ('Cosmos,' vol. iii. p. 291). Schwabe of Dessau, whose works the illustrious author quotes, observed the solar spots from 1826, and, during the whole period, found three maxima (average number 300,) and two minima (average number 33,) the period being about ten years, or the tenth part of a century. Wolf of Berne ('Comptes Rendus,' vol. xxx.) considers the period of the minima as definite, but that the maximum varies, being on an average five years after the minimum, and that nine minimum periods exactly make up *each* century; adding, that all the notable apparitions of solar spots on record agree with this rule. Other papers on this subject will be found, with details in the 'Ast. Nach.' and 'Pogg. Ann.,' from 1850; and in 'Silliman's Journal,' vol. xxv., some remarks of Reichenbach are worthy of attention. He observes that the period of Jupiter is 11·86 years, and that there are certain coincidences between the planet's periodic returns and those of the solar spots,—adding that their conjoint magnetic effects upon our planet, in relation to the magnetic periods above referred to, cannot but be great. See also 'Gilbert's Annalen,' vols. xv. and xxi., for Ritter's memoirs on the subject; and "Hansteen on the Relations between Earthquakes and the Aurora," in 'Bull. de l'Acad. de Bruxelles,' 1854, t. xxi.

I am myself indebted to my friend Dr. Robinson, Astronomer Royal, Armagh, for much of my information upon the subject, which connects itself with our own in relation to the preceding reflections, and through the singular point of coincidence as to periodic recurrences in both—the one presenting traces of being in time a submultiple of the other. But at present this must all be taken for what it is worth, *and no more*.

It may be suitable to remark here, that the movements of the inclination magnetometer as well as of the barometric column, of which several have been of late years recorded as occurring at the time of earthquakes, are most probably merely mechanical and due to the shock movements direct. This has been ascertained by Kreil at Vienna, and Padre Secchi at Rome (see also Perrey's 'Mem. Europe and Africa,' p. 11); and such appears to have been Humboldt's view (though expressed with some qualification) at the date of publication of 'Cosmos.'

The following is a translation of Zantedeschi's expressions of his own views as to the occurrence of a terrestrial, or rather *terrene tide*, probably better named, if it exist, *the elastic tide*:—

"On the Influence of the Moon upon Earthquakes, and on the Consequences probably derivable as to the Ellipsoidal Figure of the Earth and the Oscillation of the Pendulum. By M. F. Zantedeschi." *Comptes Rendus, Séance du* 2 *Aout*, 1854.

"I have thought for a long time that the form of the earth cannot always be the same, but that it presents an incessantly changing elliptical form, that is to say, having a continued tendency to become protuberant in the directions of the radii vectores of the two luminaries which attract it, the sun and the moon. I have always believed that a direct proof of it might be obtained by determining a point in the heavens at the epochs of the spring tides, and at that of the Quadratures. This point must appear lower at the epochs of the high tides and of the Syzygies. The Imperial Observatory of Paris, with the means that it has at its disposal, could prove if this difference be observable, and especially now, that, thanks to the labours of M. Froment, dividing has been made so exact as to admit of measuring with the greatest precision a difference of $\frac{1}{500}$th of a millimetre between two consecutive visible horizontal lines.

"I have always assumed that a compensation pendulum of such a length that it exactly beats seconds at the epoch of the quadratures and of the neap tides, must beat more slowly at the epoch of the spring tides, from the transit of the moon over the meridian of the given place, and at the epoch of the syzygies; and, taking from this fact that the variations of the force of attraction upon the mass of the earth are continuous, I have concluded from it the necessity for astronomy to take account of these times; and herein I find the explanation of certain leaps of astronomical clocks of which the learned have not hitherto been able to discern the cause. I believe that one day we shall have the equation of time in functions of the variations of intensity of the planetary attractions, and of the regular oscillatory movements of the earth, as we now have the equation of time in functions of the motions of translation and of rotation of the earth itself. I say the *regular* oscillatory motions, because, as for the irregular movements, we cannot submit them to rule, and we are enabled to account only for the extraordinary concomitant phenomena presented by the atmosphere, by the earth, and by certain species of animals. The irregular motions which we call earthquakes, happen more frequently, it has been observed, either at the epoch of the Syzygies rather than at the epoch of the Quadratures, or oftener at the epoch of spring tides than at that of the neaps. This important observation is found in the works of Georges Baglivi and Joseph Toaldo.

The first, in his 'Storia Romani Terræ Motus, anni 1703,' says, "In singulis lunæ aspectibus, seu quadraturis, potissimum in plenitudine ejusdem seu totali oppositione cum sole, certo succedebant terræ motus, frequenter paululum præcedebant ipsos aspectus."—Georgii Baglivi Opera Omnia, Bassani, 1737, p. 415, Editionis Venetiarum, 1752, p. 326.

Toaldo, speaking generally of earthquakes, says, "the late M. Bouguer in the account of his voyage to Peru speaks much of earthquakes, so frequent in that country. He mentions with doubt the assertion of a Peruvian 'savant,' that earthquakes have certain fatal and marked lines when they occur at low water. On the other hand, Chauvalon, in his voyage to Martinique, notes particularly the earthquakes which took place at the time of high water; and the earthquake which destroyed Lima on the 28th of October, 1746, occurred at three o'clock in the morning, at the instant of high water (ora della prima acqua). Thus we remark in other countries *that these* phenomena may themselves depend on the cosmical causes of the action of the sun, and especially of the moon." (Giuseppe Toaldo, 'Della Vera Influenza degli Astri, etc., Saggio Meteorologico,' Padova, 1770, p. 190.) I hope that the Academy of Sciences will well receive these documents and these ideas, which tend to augment the merit and the value of the very important studies of M. Perrey.

Edmonds, also, has endeavoured to show that many formidable earthquakes are found to have occurred the day after the moon is in her first quarter ('Journ. Polytec. Soc. Cornwall,' Note 158; Sabine's 'Cosmos').

Before dismissing the subject of other earthquake catalogues, the following labour as to Indian earthquakes should be noticed. In the 'Journal of the Royal Asiatic Society,' vol. xii. n. s., for 1843, Lieut. R. Baird Smith, B.E., made one of the most extensive contributions to our slender stock of oriental earthquake annals. He divides India into nine earthquake tracts, partly on physical grounds, partly arbitrarily, viz.—

1. Central Himalaya;
2. Lateral Himalaya, including—
   - *a.* Cabul,
   - *b.* Jellallabad,
   - *c.* Cashmere,
   - *d.* Nepaul,
   - *e.* Assam;
3. The Solymaun Mountains,
4. The Aravulli Mountains,

5. Delta of the Indus,
6. The Vindhya Mountains,
7. Delta of the Ganges,
8. East Coast Bay of Bengal,
9. Eastern Ghauts;

and under these divisions describes more or less fully a total number of 162 earthquakes, which he finally tabulates, by date and place only. The epoch of his catalogue commences nominally at A.D. 1505; but almost the whole of the catalogue refers to the 19th century, and comes down to the year 1842.

After his remarks upon the earthquakes of the first region (p. 1039), he observes, "The hot springs, I believe, owe their high temperature to internal chemical action extensively distributed; and the earthquakes are due to the convulsive efforts of the elastic matter generated by this action in escaping from the interior of the earth." . . . "To define the nature of this action, while ignorant of the chemical nature of the springs, would be in vain;" . . . . but . . . . "I cannot resist the conviction that both are due to one and the same origin." . . . . "There are no active volcanic vents yet discovered in the Himalayas, but abundant hot springs and trap dykes, and evidences of disruptive action."

In the same vol. p. 741, a translation, by A. Sprenger, of the Arabic MS. in the Imperial Library at Paris, of a work of As. Soyuti on earthquakes, is given. The original work is entitled, 'Kashf as salsalah'an wass az Zalzalah,' *i.e.* "a clearing up of the history of earthquakes." It contains a catalogue of about 120 earthquakes in Western India, Persia, and Caubul, and extending to Arabia, Syria, and Egypt. It certainly, however, scarcely warrants its title, and contains few facts of scientific value.

Again (p. 907), a small catalogue of earthquakes in Upper Assam occurs —the authors, Capt. Hannay and Rev. N. Brown. The chief statement of importance to be found in it is their opinion, that in this region the horizontal direction of shock seems to be mainly from S.W. to N.E.

Since the publication of former 'Reports,' some monographs of single earthquakes have appeared; but reference is here only to catalogues.

While these sheets have been passing through the press, the work of Dr. Otto Wolger, with catalogues of the Swiss earthquakes, has appeared, and demands notice for the extreme accuracy and care with which the volumes have been produced,—'Untersuchungen über das Phänomen der Erdbeben in der Schwitz,' von Dr. G. H. Otto Wolger, Gotha 1857, 1858, 3 vols. 8vo. The first, "Chronic der Erdbeben in der Schwitz," also embraces a discussion as to the periodicity, locality, and extent (Ausdehnung) of the Swiss earthquakes, with the results graphically reproduced.

The second contains the geology of the Canton of Wallis, in which so great a number of rapidly recurrent feeble shocks have been so long recorded.

The third, 'Geschichte der Erdbeben (im Wallis) des meteorologischen Jahres 1855,' together with a chronicle of those in the Swiss Cantons and adjacent parts of France.

There is an excellent though small map of the Canton of Wallis, showing the points of observation of the many small shocks that have become identified with the name of Pignerol as a centre—and in several instances showing the horizontal directions observed—which quite bear out the observations to be found further on, as to the effects of surface in perturbing the general emergent direction of the wave of shock.

The work of Dr. Wolger is entitled to the study of physical geologists.

Perhaps, like most men who carefully and lovingly perfect their subject, he attaches a too preponderant value to the limited district of which he treats.

Having so far considered the labours of others as to the distribution of earthquakes in time, some remarks remain to be made on their distribution in space by foreign authors. The seismic map of Berghaus in his 'Physical Atlas,' is the most important attempt of this sort emanating from abroad. The following are Perrey's remarks upon this map ('Mém. de l'Académie des Sciences de Dijon,' t. iv. année 1855, p. 57):—

"M. Berghaus, of Berlin, has devoted map No. 7 of the geological part of his beautiful Physical Atlas to volcanic and seismic manifestations. Greenland is very slightly coloured, and is included in the circumference of a circle of percussions, the centre of which is in Iceland. This statement does not appear to me to be at all supported by facts. The author appears to have outstripped observation; for the commotions in Iceland constitute an almost local phenomenon; rarely ever is the island simultaneously shaken in its entire extent, and the shocks are only of moderate intensity."

It may be added, that observation points out that the connexion as to earthquake commotion is between Iceland and Norway, and not between Iceland and Greenland. Of the latter country, however, in this respect we know but little.

As to Greenland, I do not know whether any earthquake has occurred there but that of November, 1755. That was violently felt; it caused a terror so much the greater, as shocks of this nature were completely unknown. However, it is probable that they are occasionally felt.

The 22nd of September, 1757, there was a violent hurricane, the wind from the south, accompanied by hail and rain; the lightning was terrific, but without thunder. It was generally believed that a shock of earthquake was felt. (Prévost, 'Hist. Gén. des Voy.' t. ix. pp. 23 & 209.) Earthquakes, the author adds, are rare in this country.

Two years after, in September, 1759, at New Herrnhut (Greenland), the house of Siehlenfels experienced shocks like an earthquake, although it was very low and had walls four feet thick. The houses around suffered severely: the roofs were split; and the boats drawn up on shore were carried away by the hurricane, which was felt at a distance. This storm was preceded and followed by igneous meteors, one of which set fire to the house. On Christmas Eve a similar phenomenon occurred at noon. (Prévost, *l. c.* t. xix. p. 208.)

These are the only facts that I can quote relative to this country, which, I repeat, notwithstanding its contiguity to Iceland, ought not, in my opinion, to be placed within the sphere of the volcanic and seismic action of that island.

M. Berghaus has marked the Azores and Canaries with a darker shade; and this memoir will contribute to confirm the author's idea of also colouring the Archipelago of Cape Verd and the Antilles. But it leaves all the rest of the basin uncoloured; and surely it is difficult not to admit some shading, however slight, in latitudes distinguished of late by M. Daussy. Let us again repeat, that earthquakes, which ought to form an important part in the study of terrestrial physics and physical geography, have hitherto been too much neglected. They have been resigned to geology, to which, in my opinion, they only indirectly belong.

But to continue. Algeria bears, on M. Berghaus's map, a very dark shade, which the note I published in our last 'Memoirs' does not justify. Yet the illustrious physicist whom I have just quoted includes the Azores and Canaries in the seismic region of the Mediterranean.

They would seem to form the western part of an axis which extends to Hindostan with variable shades, and thus unites the Atlantic with the great volcanic chain of the Sonde (Sunda), which, as we know, is connected by the Japanese and Kurile Islands with the Aleutian Archipelago, and by this chain to the grand volcanic range of the two Americas. This idea is ingenious, but is it true? It is a point that I cannot at present discuss. Yet we must admit that the Azores, and even the Canaries, seem to form a part of the sphere of subterranean convulsions, the centre of which is almost parallel to Lisbon; and to be at the western extremity of that great seismic zone which proceeds by the peninsulas of Spain, Italy, and Greece, to the volcanoes of Asia Minor, and which there joins the central chain of Asia. It is, in fact, within this zone, extending towards the north as far as the Carpathian Mountains, that the principal centres of earthquakes and the most remarkable seismic axes in Europe are to be found. Extending to the west along the 40th parallel, this zone reaches the United States of America, where it embraces New York and Boston, which M. Berghaus has perhaps marked with a rather too dark colour, though earthquakes are not rare there; and thence it proceeds to Kentucky, Tennessee, and Missouri, where the phenomena of the year 1811 demand a darker shade in M. Berghaus's beautiful map. M. Berghaus draws a linear region in Arabia, from Medina to Yemen, along the east coast of the Red Sea. Can this be a partial axis of convulsion? Is it independent of the Mediterranean zone? Or is it united to it by a second axis—the Syrian axis, parallel to the east coast of the Mediterranean? But the countries near to the Isthmus of Suez appear little subject to earthquakes; can there be a solution of continuity between these two axes? or does the space which divides them, and where the phenomenon has, so far, been so rarely remarked, constantly present a peculiarity verified more than once in America? In the New World (at Caraccas, for example) certain regions of small extent have been observed to enjoy a complete calm while the neighbouring country experienced frightful catastrophes.

The historians of these disasters have characterized this unconvulsed part of the soil by a picturesque expression, namely, "a bridge has been formed." The probable physical explanation of this phenomenon of "the bridge" has been given in a former Report (2nd Report, p. 309), by the author of this, based upon the view that *total reflection* of elastic impulses may occur under certain suitable conditions.

Perrey continues, "No simultaneous convulsions at both extremities of this Syro-Arabic linear region have been recorded. However, if we recall that the Himalaya Mountains are very subject to subterranean convulsions; that the Alps, and especially the Pyrenees, are frequently shaken, the Caucasus-range still oftener, and that the Andes are almost always in a state of commotion; must we not regret that we possess no information concerning the phenomena in the high Ethiopian chain? is it not to be desired that travellers in Africa should make observations upon a matter so interesting to science?

"During the last few years Abyssinia (strongly marked in M. Berghaus's map) has been the study of numerous French explorers. Several narratives of their vast and useful labours have appeared; but I do not find one word about earthquakes! The Academy of Sciences has just given new instructions to M. Rochet (d'Héricourt), about to undertake a third expedition to that country; and the phenomenon is not even mentioned by M. Duperrey!

Quite recently, again, I felt the same painful surprise at reading the instructions given to M. Raffenel.

"Does Abyssinia form an axis of convulsion perpendicular to the Arabic axis? or is it the eastern extremity of an unique axis formed by the great Ethiopic chain, and crossing the African continent at its greatest breadth?

"In nearly the same latitude as Abyssinia, but on the western coast of Africa, we find the sources of the Senegal and Gambia vividly coloured in M. Berghaus's map. What evidence has the author for this statement? With respect to this region, I am only acquainted with the two following descriptions drawn from M. Walcknaër's collection." We read, at t. vi. p. 181, "The aspect of the mountains Nikolo and Bandeia prove that this country has been the theatre of volcanic eruptions. Earthquakes are very frequent; and shortly before M. Mollieu's visit, one of the most violent had occurred, the shocks of which had been felt as far as Timbo." And further on, p. 184, "The mountains, covered with ferruginous stones and cinders, which enclose the valley in which are the sources of the Senegal and Gambia, lead M. Mollieu to believe that they occupy the crater of an extinct volcano. This traveller was at the source of the Gambia, April 8, 1818."

It is useful to compare this passage with the following, extracted from the same collection, t. xii. p. 356:—"There is no record in Senegal that any portion of the colony has ever experienced an earthquake."

Without seeking to justify the accuracy of M. Berghaus, it may not be uninteresting to remark that the Antilles and the Republic of Guatemala lie under the same parallel of latitude (about 15° N.) as Abyssinia and the sources of the Gambia.

Can there be an axis, or rather an immense zone, of convulsions parallel to the Equator? Often convulsed in the western counterforts (the Archipelagos of Cape Verd and the Canaries), Africa suffers also in the S.E., in the great southern chain of Madagascar. I find in M. Seguérel de la Combe that "earthquakes are very frequent in Madagascar. When they occur, the natives leave their houses and commence beating the walls with their hands. They do not allege any reason for this conduct but custom." ('Voy. à Madagascar et aux Iles Comorres,' t. i. p. 3.)

Let me add this remark from an ancient traveller in Madagascar: "Happily earthquakes are here completely unknown." (Le Gentil, 'Voy. dans les Mers de l'Inde,' t. ii. p. 367.)

If we subjoin to these contradictory statements the few facts which we possess, we shall justify M. Berghaus's not having coloured the south of Africa.

"1786, August 4, 6·35 A.M., in the Isle of France, two violent but harmless shocks. The motion was horizontal and vertical. The barometer was not affected. Earthquakes are of rare occurrence. The volcano in Bourbon, active from the 5th of June previous, emitted much lava upon this day, but the island was not sensible of any shocks." (Péron, 'Voy. aux Terres Australes,' 2nd edit. t. i. p. 134; 'Ephémér. de Manheim,' 1788, p. 397.)

1809, 8th of January, the island of Penguin, close to the Cape of Good Hope, was swallowed up by an earthquake. I am unacquainted with this island, and I only find this circumstance related in an anonymous work entitled 'Mémorial de Chronologie,' t. ii. p. 932.

Here, again, relative to another earthquake of the same year, 1809, are the details communicated by M. Barchers, Minister of Stellenbosch (country of the Hottentots), to Campbell (end of November 1812), concerning the first of the earthquakes which occurred three years previously:—

"The church of Paarl was then vacant. The governor begged me to preach there once a month. On Saturday, the eve of the day on which I had to go there, I felt extremely ill and dejected. On Sunday morning my wife and I set out. When I reached Paarl, I was very weak, and asked for some water; but it was lukewarm, and I could not drink it. I was told it had been brought from the fountain. I sent my slave, but what he brought was hot. I went thither myself, and found it was really the case. We could not imagine the reason. Whilst I was preaching, I felt so giddy that I scarcely knew what I was saying.

"After the sermon, I spoke of this sensation to several of my friends, who declared that they also experienced it. We returned to Stellenbosch on the following morning. The whole of that day my family and servants and myself felt very unwell; the dogs also shared in our uneasiness.

"At 10 o'clock we were all alarmed by a noise like that caused by numerous carts rolling through streets. We did not know what it was; but all my family were terrified. A great light shone into the room. Supposing that a thunder-bolt had burst, I exhorted them not to be alarmed, as the lightning had passed, and the danger was gone. Whilst I was speaking, the same noise which we had just heard was again repeated, and we all trembled. 'Oh!' cried I, ''tis an earthquake; let us all go into the garden.' We felt, to use a Scriptural expression, that 'there was no more life in us.' A third shock followed; it was less violent than the first two. The noise was dreadful, not only owing to its loudness, but also to its nature. I can only describe it as a sort of groaning, or piteous howling. The dogs and birds testified their fear by their cries. The night was calm, not a breath of wind stirred the air; but I remarked a number of luminous meteors. I observed small clouds in various quarters, but their aspect presented nothing new. Every one endeavoured to keep close to me; alarm was excessive; I said what I could to allay it. At last we ventured to return to the house, and endeavoured to sleep to recover ourselves; but the effort was vain." (Walckenaër, 'Collect. des Relat. de Voy. en Afrique,' t. xviii. p. 275.)

1810, in the depth of winter an earthquake occurred at the Cape of Good Hope.

1811, 2nd June, five minutes before 12 o'clock noon, another earthquake took place. The heat was greater than usual at this season, the thermometer was 16°·8 R. A thick mist filled the atmosphere, yet did not obscure the sun's rays; not the least breeze disturbed the air. The inhabitants, who greatly dread subterraneous shocks, were reminded by these symptoms of the earthquake of the preceding year. M. Burchell was busy indoors with preparations for a missionary journey, when suddenly a noise like an explosion shook the entire house. Three or four seconds afterwards a second peal like thunder produced another shock; at the same instant a singular motion and vacillation in the atmosphere was apparent, whilst the sky continued perfectly serene. M. Burchell ran out to discover what had occurred; he saw all the inhabitants running out of their houses in great alarm, pale and trembling, not conscious what they were doing, the women either screaming with terror, or motionless and incapable of speech. After the second shock, the trembling of the atmosphere had ceased, and the temperature a little cooled. The people gradually regained their composure, observing that no more shocks followed. Many houses were injured, and walls split.

This earthquake took place five minutes before noon, during the Cape winter; the preceding year it occurred during the night, in the height of summer: so this phenomenon is not limited to any time of day or year.

M. Burchell saw the trace of electricity in all the preceding symptoms, and can only explain the earthquake as an explosion of electric matter.

On the morning of the 19th another shock was felt, but unaccompanied by explosion or other consequences. A slight sound was heard, which appeared to travel from N. to S., and lasted about three seconds. (Walckenaër, *loc. cit.* t. xx. p. 20-22.)

To these facts we may subjoin the following:—

1811, 7th June, at the Cape of Good Hope a violent shock of five minutes; the houses tottered, and even the vessels in the bay felt the shock. (J. D. 14th Nov.; M. U. 15th Nov. 1811.)

1818, on the night between the 28th Feb. and 1st March, in the Isle of France, a hurricane similar to that of 1716; it is alleged that shocks of earthquake were felt. (J. D. 21st June 1818.)

1821, 9th March, in the Island of Bourbon a slight shock. The eruption of the volcano, which had commenced on the 28th February, still continued. (C. P. t. xxxiii. p. 404; Garnier, Météor. p. 124.)

1840, 7th July, in the Isle of Bourbon, earthquakes recorded without detail by M. Meister in the Annalen für Meteor- und Erdmag., 1er cahier, p. 161.

1844, 21st Feb., 8 P.M., in Isle of Bourbon, shocks and terrible wind (communic. de M. Meister.)

If we add to these five or six earthquakes the eruptions of the volcano in the Island of Bourbon in 1708, -51, -66, -74, -86, -87, -91, -93, and 1800, we shall have all the manifestations which I can quote of the interior activity of the globe in the south of the African continent. So this part of Africa appears little subject to subterranean commotions. But is it the same with the interior of the country? It would be very interesting to learn this.

Johnston, in his Seismic Map (Phys. Atlas, No. 7, Geol.), lightly tints the southern extremity of Africa, left untouched by Berghaus.

To these remarks of Perrey may be added, that both Berghaus's and Johnston's seismic maps alike labour under two most important defects.

First, a hard and rigid line, often of an extremely irregular figure, limits strictly and definitely the supposed boundary of seismic commotion in each assigned region. Two physical misconceptions are involved in this: first, that forces emanating from a centre, of the nature of earthquake shocks, can have any definite boundary; secondly, that a line drawn upon the earth's surface around any centre of impulse, and through a number of points at which the horizontal elements of shock are alike (suppose those at which these elements become insensible without the help of instruments, which would be the boundary line in a popular sense), can possibly have, when embracing large areas, a highly irregular though closed curvilinear figure. The curve traced through such a line of points must circumscribe a space either nearly circular or slightly elliptic; all irregularities due to variation of surface vanish over such vast spaces.

Irregular curved areas are alone possible on the assumption of more than one impulse propagated from the same origin simultaneously, of which we have as yet no evidence.

The second defect common to both those maps, and possibly difficult to be avoided from their small scale, is the absence of any positive and invariable, though conventional principle of application of the *depth of tint* in colouring, which shall determine, by its depth, the intensity and frequency of seismic action at given centres.

The principles adopted with the seismic map attached to this report will be explained further on.

Berghaus's maps (3 Abtheil. Geol. No. 7 und No. 9) give an exceedingly imperfect notion of the whole east of China, and indeed of the Sunda and Philippine Island groups, including Luzon, incomparably the most important and interesting earthquake region on the face of the earth. Berghaus's maps, 3 Abtheil. Geol. No. 8 und 10, "Specialia vom Vulkan Gürtel," &c., are worthy of all commendation, save as respects the outline of seismic regions already adverted to, and here repeated even in a more distorted form.

Such have been the results of previous labours as to the distribution in time and space of earthquakes. I proceed to those deduced from our own researches.

At the conclusion of the Second Report (1851), the principles upon which the British Association Earthquake Catalogue itself was compiled have been described; it remains now to describe the methods by which it has been discussed, and to state the results.

The collection of an earthquake catalogue is a work essentially of a statistic character, and partakes of all that disadvantage and incompleteness that belongs to the collection of facts not the result of choice and experiment, but presented to us, through various and imperfect observations, from many places and through long-lapsed periods, during which all the conditions of observation have suffered much change, so that the facts that are presented for record, and those of which no account is given, are alike subject to certain contingent or accidental modifying conditions, but of such a nature as to defy our making them part of our discussion.

So in a work which proposes to collect under one view the transmitted observations of the whole human race, and of all historic time on this particular subject, the conditions of human observation itself enter into the results, and our earthquake record is at once an account of these phænomena, and of the rise, progress, and extension of human knowledge and observational energy, and also of the multiplication and migrations of the human family and its progress in maritime power; in a word, at every moment the indeterminate extent to which man has fulfilled his great destiny of "replenishing the earth and subduing it," affects every continuous record of his observations or his arts.

The method of discussion followed was that of numerical analysis as to time, and topical analysis as to space, from which curves graphically representing the results have been projected by the usual methods.

One conventional arrangement has been found inevitable. It refers to the cases of long-continued slight shocks or tremors, occurring almost daily, as at Pignerol in 1808; St. Jean de Maurienne in 1839; Comrie, in Perthshire, 1839–1847; and Ragusa in 1843–1850. In these the slight shocks recorded for each month of the disturbed period are grouped as forming one earthquake at the locality. Had not some such arbitrary rule been adopted, these comparatively insignificant, though frequently repeated exhibitions of seismic force (if they be such) would, when introduced in the curves, have given, at certain points of time, a false elevation to the abscissæ, while the phenomena themselves are not of a character materially to modify our results even if excluded.

The conclusions possible from the still vast mass of facts here brought together, however, will, as a first generalization, be found, I apprehend, not unimportant.

They may be classed under two great heads; viz. the relation of seismic energy to time and to space, or the distribution of recorded earthquakes in each. And, first,—

Of Seismic Energy in relation to Time.

Plates I. II. III. IV. V. and VI. carry down the stream of time the whole series of observations from 2000 years before the Christian era to the year 1850.

In all these chrono-seismic curves the ordinate is that of *epoch*, and must not be confounded with one expressing in anywise the duration of each shock or separate seismic effort. The abscissa is that of seismic intensity, which has been assumed proportional to the number of coincident seismic efforts, without taking any account in the curve of the variable intensity of different efforts. This is a source of uncertainty that would not have been avoided, but rather the tendency to error increased, by any conventional law of enlargement of the abscissa that could have been devised to suit the vague proportion of greater or less in earthquake narrations; but the means are given to the reader of applying such corrective as the information admits, by placing along the line of time down to the year 1750 the letter G above each epoch at which an earthquake of undoubtedly great and destructive intensity has been recorded, and the letter S above all those that were so circumstanced as to have been followed by the influx of "great sea waves." This notation might have been carried on further, but that after the year 1750, when observations rapidly multiply, the number of earthquakes recorded as being "great" are so numerous, that to distinguish their epochs thus would have involved the extension of the ordinate to a new and inconveniently enlarged scale. For the first three centuries of historic time (according to our commonly accepted chronology) it will be seen that there are no earthquake records, and that, while between A.C. 1700 and A.C. 1400 there are a few scattered facts, there is again from A.C. 1400 to A.C. 900, nearly a period of five hundred years of perfect blank, followed again (with a few exceptions) by another blank from A.C. 800 to A.C. 600. Even in the succeeding century, but two earthquakes are recorded; so that, in fact, the record of any value for scientific analysis may be said to commence at the five hundredth year before the Christian era.

It is only in the first century prior to our era that the curve shows that observations may be at length deemed even continuous, every previous century being interrupted by lengthened lacunæ.

From the commencement of the Christian era downwards to the present day, the abscissæ continually increase in closeness and magnitude, and at the first casual glance suggest the idea that earthquake energy has increased over the whole earth during the course of ages in a fearful manner. We shall see, however, reason to correct any such conclusion.

Although periods of thirty and forty years occur in the second and third centuries of our era without the record of a single earthquake, it did not seem advisable to affirm as certain the want of all observation, by the substitution here of lacunæ for the continuity of the curve.

The end of the third century first gives evidence of numerical increase; and the increase thence is steadily progressive up to the year 1850.

It is not, however, until the seventeenth century that the increased number of earthquakes becomes strikingly remarkable, increasing still more in the eighteenth, and presenting a far greater number in the first half of the nineteenth than in both the preceding centuries taken together.

Yet this vast and rapid expansion, in the three last centuries especially, affords no proof whatever that there has been a corresponding, or even any increase in the frequency of earthquake phenomena. Our chrono-seismic curve is, in fact, not only a record of earthquakes, but a record of the advance of human enterprise, travel, and observation. The epochs of printing and the Reformation are those of the first great expansion, while the discovery of the new world, the voyage to India round the Cape, and the vast accessions of European colonization and commerce of the last 150 years, connect themselves as causes with the two latest curves. We have traced at once the history of a physical law and that of human progress. How far, then, is it possible to disentangle these elements, so as to arrive at a conclusion as to whether seismic energy over the world is progressive, constant, or retrogressive? To do so perfectly is perhaps impossible; the elements by which the rate of observational knowledge has been determined are too complex and too imperfectly known to render any attempt to fix its rate of expansion in time probable. Even the area of observation itself, the land and water known to history at given epochs, can be but vaguely sketched; as vaguely also the number of observers, and the determination of the human mind towards observation. (See Appendix I.)

This much is certain, however;—that up to, and even beyond the Christian era, no record of earthquakes exists for any portions of the earth's surface, except for limited areas of Europe and Asia, and a still more restricted patch of Northern Africa, and, if Kaempfer is to be credited, for Japan, of which, however, we know nothing for certain. Yet, of the enormously larger areas of the then outer and unknown world since discovered, it is not to be supposed but that there was a proportionate (perhaps even for the "New World" a more than proportionate) amount of earthquake energy, though not recorded or even known to mankind.

If, however, the curve of total energy (Plate VII.), in which the facts of all the preceding are condensed into a single line, be examined and compared by a broad glance with the great outlines of human progress, the conclusion appears sufficiently warranted, that during all historic time the amount of seismic energy over the observed portions of our world must have been nearly constant. To assume that earthquake disturbance has been continually on the *increase*, would be to contradict all the analogies of the physics of our globe. These analogies might lead us to suppose that, like other violent presumed periodical actions, they were getting spent, and that the series of earthquake shocks would be found a converging one. Were this so, however, to any considerable extent, we should not find the vast expansions of results which the last 300 years present; or, although the expansion might be absolutely large, its divergence would not present such decisive features of progressive increase. The results due to the number of observers would be more or less balanced by the increasing paucity of events to observe and record; but this appears conclusively to lead to the deduction we have made, namely, that if the curve of total energy be closely examined century by century, it will be found that, at periods of social torpor and stagnation of observational energy (and this is so even far down the stream of time), the number of earthquakes remains nearly constant, or with a very slight but nearly uniform increase. Thus, from the eleventh to the beginning of the fifteenth century, the abscissæ are almost equal, the crests of the curves being nearly all ascribable to single great earthquakes, which made themselves felt over vast areas. Their expansion just keeps pace, so far as can be judged, with that of contemporaneous human progress; but if the series was really a distinctly converging one, at such periods we should find the abscissæ decreasing also. On the other hand, we find the increase in the number of recorded earthquakes always coinciding with the epochs of increased impulse and energy in the march of the human mind.

We therefore conclude that our evidence, such as it is, indicates a general uniformity in the occurrence of earthquakes as distributed over long epochs of time. Setting aside (as contradicted by all other sources of analogy and information) the supposition that this, or any other phenomenon of occasional disturbance, has an increasing development upon our planet, we have two remaining alternatives;—either that seismic energy is getting gradually spent and is dying out—this, the evidence before us appears sufficiently to contradict; or that, upon the whole, during our short and most imperfect acquaintance with it, it has remained pretty uniform throughout historic time, taking one long period with another. Yet, could we extend our view beyond the short limit of man's history to the vast past duration of that of our globe itself, it might be found that seismic energy is really a slowly decreasing force.

A conclusion thus appearing at the first glance even contradictory to the presented results from which it is drawn, may bear a certain boldness of aspect, for which I hope to find that the observations preceding, as to the true character of all earthquake records, and of the sort and amount of stress that may be laid upon them, will be held a justification.

But while such uniformity or insensibly slow decadence may be the fact through time taken as a whole, there is also evidence of irregular and paroxysmal energy in reference to shorter periods; that is to say, not only (as all know) do earthquakes occur at some times, and not at others, in any given spot; but, taking the whole area of observation together (in which there is no moment, perhaps, or but a very brief one, wherein there is not an earthquake somewhere, or more than one), it will be found that there are epochs when they occur in greater numbers or intensity, either in the same or in several places within a limited time,—*i.e.* periods of paroxysmal energy.

If we omit from our view all the curves of earlier periods and less ample observation, and limit our consideration to those of the last three centuries and a half, *i.e.* from A.D. 1500 to 1850, this paroxysmal character becomes evident at a glance, and increasingly so in the last century and a half (the epoch of all human history the most replete with discovery), wherein the number of recorded observations is so great, that it was necessary for clearness to double the scale, of the ordinate of the diagram (Plate VI.) in relation to the preceding ones. On examining these curves, they seem to justify the following deductions:—

1. While the smallest or minimum paroxysmal interval may be a year or two, the average interval is from five to ten years of comparative repose.
2. The shorter intervals are in connexion with periods of fewer earthquakes —not *always* with those of least intensity, but usually so.
3. The alternations of paroxysm and of repose appear to follow *no absolute law deducible from these curves.*
4. Two marked periods of extreme paroxysm are observable in each century—one greater than the other—that of greatest number and intensity occurring about the middle of each century, the other towards the end of each.

This is one of the most remarkable facts that these curves seem to point to: from about the fiftieth to the sixtieth year of each century, both the number and intensity of earthquakes will be observed suddenly to shoot up; again, during the last quarter of the three complete centuries another but less powerful paroxysm is apparent. The paroxysmal power at these two epochs in each century far exceeds any other paroxysms within their limits.

Within the first period (in the 18th century) we find the great Lisbon earthquake; within the second, in the same century, the great Calabrian one. We find (referring to the Catalogue itself) earthquakes in great numbers, and many great ones—in the Mediterranean basin in the middle of the 17th century, and the great Jamaica earthquake in its latter decade; and in the 16th century, its middle period was marked by great earthquakes in China and in Europe, and the latter period by numerous shocks, and most of them severe, as at the Azores, &c. Whether the latter half of our century shall show the like, remains to be seen; from its commencement, however, it presents no paroxysmal period comparable to that between 1840 and 1850.

While this general resemblance of the curves of these latter centuries admits of no doubt, I would forbear from founding anything thereupon beyond this;—that within this time there seems to elapse a period of about a century between each of the *very greatest* paroxysms (number and intensity together) of earthquakes, and a like period between two other consecutive paroxysms, of which the second is the next greatest observable, although far below the first in power; that a period of thirty to forty years seems to occur between the first and very greatest paroxysm, and that next in power below it; and that in the middle period (especially in the 17th and 18th centuries) the number of earthquakes is greatest that crowd into a very brief time (four or five years), while at the latter period the number is thickly spread over ten or twelve years.

Upon the whole, the forms of the curves appear to indicate a comparatively sudden burst of seismic energy at each great paroxysm, and (by their flat tops or more sloping lines to the right hand) a more gradual subsidence, as if the train of causes required time to regain, after one spent paroxysm, their energy and regimen, which, when restored, were suddenly put into action, and which, once developed, were slow in being wholly expended and relapsing into repose.

The occurrence of such epochs at the middle, or towards the end of our purely arbitrary subdivision of duration into centuries, must be of course only accident. The interval of *duration between* one epoch and the next, is that alone which can have a cosmical basis.

We may then provisionally affirm the probability of two periods of earthquake maxima—a greater and a less alternately—as occurring in a hundred years, for the last three centuries of history at least. The existence of *some* periodic maxima in remoter centuries can hardly be doubted, although the epochs of the two maxima have a secular movement, and do not fall in the same place in the older times. Anterior to the 16th century, however, the general curves of time (Plates I. II. and III.) are, through paucity of observations, not sufficiently "prononcées" to enable this to be asserted from them, or to warrant the graphic representation of the epochs of occurrence of such paroxysmal periodic maxima for the whole even of the Christian era.

In Plate VII. fig. 2, the periods of paroxysm (number and intensity) are summed and grouped for each successive century of our era. The 1st, 5th, 9th, 12th, and 18th centuries are those of greatest seismic development, while the 1st and 2nd centuries A.C., and the 3rd, 7th, 10th, and 14th centuries of our era, are times of comparative repose. The numerical value of the paroxysmal centuries (as we may term them) increases, though not regularly, as the present time is neared, and is modified, without doubt, by the same conditions of observation that affect the expansions of the later curves of time. We dare not base any generalization upon it.

Numerically, we find the following average ratios of earthquakes for the successive historic groups, of time extending over the whole record of the catalogue :—

TABLE XXIX.

Historic Group.	Ratio per Month.	Ratio per Year.
2000 to 1000 B.C.	0·00033	0·004
1001 B.C. to Christian era ...	0·0045	0·054
A.D. 1 to A.D. 1000	0·0185	0·222
A.D. 1001 to A.D. 1850	0·545	7·740
A.D. 1551 to A.D. 1850	1·450	17·370
A.D. 1701 to A.D. 1850	2·610	35·310

These numbers are absolute as well as proportional; nothing can more distinctly show the relation between the expanding areas of our curves of time and the increase of observation.

Sir Charles Lyell, at p. 428 ('Principles of Geology,' 7th edit.), calculates, upon approximate data, the average number of actual eruptions of volcanic matter at 2000 per century, or 20 per annum,—a result which harmonizes sufficiently with the preceding, and gives support to the commonly received view of the connected nature of volcanic and seismic phenomena.

This connexion receives further confirmation from the facts recorded by Perrey ('Mem. on Chili,' p. 201), as to the long duration there, of many earthquakes of a character much more violent and decisive than the tremors long continued, at Comrie, East Haddam, &c. He mentions earthquakes in 1647, 1730, 1751, 1819, 1822, and 1833, each of which lasted, with little intermission, for several months, and which, from other sources of information, seem to have been in some instances contemporaneous with prolonged activity of the neighbouring volcanic regions.

Of Seismic Energy in relation to Season.

I now proceed to such discussions as the data will admit, of the relations between seismic development and the time of year. In Plate VIII. are given the curves of mensual seismic energy obtained from the entire period of the catalogue, thirty-two centuries.

The northern and southern hemispheres of observations have been separated for the following reasons. The total number and value of the observations in each, present great disparity between them respectively. We are enabled graphically to present 5879 observational results for the northern, and but 223 for the southern hemispheres; and, for convenience, the vertical or seismic abscissa of the former is on a scale which bears to that of the latter the ratio of 100 : 1; the ordinate of time, which extends to the cycle of an entire year, and is divided and marked for the twelve months in order, is the same for both figures. As the months, in fact, involve or contain the seasons of the year, and indeed all other divisions of our solar revolution, and as the latter are unlike for opposite hemispheres, and are hereafter to be compared, such subdivision is necessary.

Examining figs. 1 and 2, Plate VIII., we find in the northern hemisphere the annual paroxysmal minimum in July, in the southern it appears to be in March. The duration of this minimum in the northern extends, with no very considerable fluctuation, over nearly two months, and suddenly rises in July; in the southern the minimum is more suddenly arrived at, and as suddenly abandoned, and it extends over less than one month.

If we take May and June as one minimum in the northern, we have a second but very much lower one in September, and the corresponding second minimum for the southern hemisphere in August.

The annual paroxysmal maximum for the northern hemisphere is distinctly in January, and for the southern in November.

January and March are second maxima in the southern, as August and October are in the northern.

Whatever be the irregularities month by month however, the preponderance of seismic paroxysm for the whole twelve months lies amongst those that form the winter of our northern hemisphere.

In Plate IX. figs. 1 to 6, curves are drawn for mensual energy, for several corresponding periods for the northern and southern hemispheres. Figs. 1 and 2 indicate these for the whole period before, and for sixteen centuries after the commencement of our era. Here the northern minimum falls in July, and a second minimum in October, while the southern minimum falls in April, and the second before September, approximating thus to accordance with the curves of the whole catalogue, but less "prononcées." Then for later but shorter observed periods, figs. 3 and 4 give the mensual energy for A.D. 1700 to 1800, and figs. 5 and 6 for A.D. 1800 to 1850, being the half century in which, for convenience of comparison, the ordinate of time is double the scale of the other figures, the whole twelve months being represented by an ordinate of equal length in all.

In the eighteenth century, then, we find in the northern hemisphere the minima less distinct, occurring in July and September, and the maximum in January, with a second maximum between October and January; and in the southern hemisphere, the minima about March and September, and the maxima in May and December.

Again, in the first half of this nineteenth century we have (fig. 5) the northern minimum in June, a second but less marked minimum between November and December, and the maximum again in January and February; while in the southern hemisphere we have (fig. 6) the seismic minimum in March, and a second but much less marked one between July and August, and the maximum in November, with feeble indications of a second slight one in June.

Such are, then, the results of our monthly discussion. Comparing both hemispheres, they show several points of general agreement, and some of decided want of accordance. Little comparative weight can be ascribed to the few observations as yet made in the southern hemisphere, where so large a proportion of the earth's surface is covered by the ocean, and where so little of the land has, until a very late date, been the subject of observational record at all. It would seem warrantable therefore not to permit any such unaccordant phenomena between the two hemispheres to obscure the strong presumption which the facts otherwise support, that there really is a seismic paroxysm in the months forming the end and commencement of the civil year. It may not have a natural or cosmical basis, it *may possibly* be one of the accidents inseparable from an observational catalogue; but both this extended catalogue, and nearly all the partial catalogues of others, indicate it as a fact, and one not absolutely without some extraneous support in the present state of our knowledge.

When we group the consecutive months into four seasons, spring, summer, autumn, and winter, and reproduce the curve of seismic energy for the whole year, and separately for each hemisphere and for the whole period of the catalogue, the same relation of scale as before (figs. 1 and 2, Plate VIII.) being maintained between the northern and southern abscissæ, we find some of the apparent anomalies disappear. In fig. 1, Plate X. the curve of season for the northern hemisphere assumes a very regular form, and gives a decisive minimum for the summer season (in May and June), and an equally clear maximum for the winter season (in December and January).

In fig. 2, Plate X. the corresponding curve for the southern hemisphere, however, still shows two maxima and two minima, the maximum at the commencement of winter, with second maximum at midsummer; the minima in spring and autumn assuming the months constituting the respective seasons reversed in the two hemispheres. It must be borne in view, however, that the base of induction for this hemisphere is from only 223 observations, against 5879 in the northern; that if the southern curve had been drawn to the same vertical scale as the northern, it would have appeared to the eye as almost a straight line; so that very little weight is to be attached to the discordance it appears to present to the corresponding curve, its necessarily exaggerated scale falsely addressing the eye.

In fig. 3, Plate X., the two curves preceding are combined, but to the same scale of vertical or of seismic abscissa; and the result shows how little in reality the data that we possess as yet for the southern hemisphere are capable of modifying the facts we have for the northern. The southern curve, in fact, scarcely alters to the eye the preceding northern one; and the new curve of season for both hemispheres presents still the winter maximum and summer minimum.

In fig. 5, Plate X., a curve has been obtained for the whole period of the catalogue and for both hemispheres, representing graphically all recorded earthquakes occurring near or at the equinoxes and solstices (the *critical epochs* of Perrey and others) within a limit of twenty days, *i.e.* ten days before and ten days after each equinox and solstice. The base of induction is moderately large, the catalogue containing the following numbers:—

Vernal equinox (March 10—30)	310
Summer solstice (June 11—July 1)..........	254
Autumnal equinox (Sept. 13—Oct. 3)	249
Winter solstice (Dec. 11—31)...............	318.

This we may call the equinoctial and solstitial curve of comparative seismic energy. It indicates a distinct maximum about the winter solstice, and an equally distinct minimum rather before the autumnal equinox. Taking the average of the whole year for any lengthened period, it may admit of much doubt, whether there is any real seismic paroxysm at the equinoxes and solstices, although a clear preponderance is shown by our catalogues at two out of the four annual epochs at which all are recorded; yet, from the accordance of Perrey's results with those given by this much larger base of induction, we cannot put aside the possibility that the fact may have a cosmical basis.

The most direct connexion in such case that we should expect to find, with other ascertained periodical phenomena, would be with the annual march of the barometer. In fig. 4, Plate X., the annual curves of mean mensual barometric pressure are laid down to the same scale of ordinate for time as the equinoctial and solstitial seismic curve below (fig. 5), giving the variation in atmospheric pressure for places in several and distant latitudes, Macao, Havanna, Calcutta, Benares; and in Europe, Halle, St. Petersburg, Berlin, Paris, and Strasburg,—the curves themselves having been reduced from those of MM. Buch, Dove, and Kaemtz.

On comparing these barometric curves with the seismic one, an obvious similarity addresses the eye. Is there any real relation, however? In the First Report (1850), p. 68, &c., I have treated of the relations of atmospheric pressure with earthquakes, and at p. 78 have indicated a possible link of connexion of a *direct* character between them, and shown how it is conceivable that local increase of barometric pressure, and diminution simultaneously elsewhere, may conspire with other conditions to bring on volcanic action, and hence earthquake; and Perrey has hinted, in his memoir on France, p. 98 (4to), at some relation between his seismic mensual curves for Italy and Europe, having a minimum in November, and Dove's barometric curves, given in Pogg. Ann. for 1843, pp. 177, 201, which show something analogous (*quelque chose d'analogue*). Here we observe (comparing figs. 4 and 5) the barometric minima very closely correspond with the seismic minima, and *vice versâ*. Bearing in mind the fact, that, as the sun gets nearer the zenith with the advance of spring and summer, the barometer falls, and that, taking the whole earth together, the atmospheric pressure is less over those portions of its surface where it is summer, and greater over those where it is winter; and that these differences of pressure are greater in general as the latitude is lower, so that simultaneously that hemispheric surface of the globe which is at the time most heated by the sun is also least pressed upon by the atmosphere, and *vice versâ*; it seems warrantable to presume a cosmical and even a possibly direct connexion between the two phenomena; and this receives, again, some support* from the fact (though not without large exceptions), that on the whole the great earthquake bands of the world pass through low latitudes, where these barometric and thermic fluctuations are most developed.

It would be worse than useless, however, to speculate minutely upon the physical relations of those facts, in the present imperfect state of our knowledge of their connexion.

The attempts which I have made to ascertain an absolute relation in number, from any discussion of the Catalogue, between the recurrence of seismic paroxysm at the equinoxes and solstices, and at an equal period of twenty days throughout the whole range of time, have been nugatory; it is impracticable to extricate a result, in which any confidence could be reposed, from the observational expansion and irregularities with the advance of time.

We must not be discouraged, however, that after the vast labour bestowed by so many, upon cataloguing earthquakes and discussing the results, we find these do not bring us even to the threshold of positive knowledge, and that the main reward of toil so far, is the having cleared away rubbish, and at length ascertained how far lists of facts, such as have been hitherto compiled from the best available materials, are of any further use. General Sabine, in his Introduction to vol. iii. of the 'Magnetical and Meteorological Observations made at Toronto,' p. vii., when narrating the former state of magnetical science as compared with its present position, says, "a few of the German observers had begun to note the disturbance of the horizontal force; but as yet no conclusions whatsoever as to their laws had been obtained:" in the words of the Report, "the disturbances apparently observe no law." Such may almost be said, as to our present knowledge of the distribution of earthquakes in time and in space, as referable to any natural law. We know how the position of terrestrial magnetism has become altered since the time referred to above by one of its best promoters; let us expect the same for seismology, and await with hope the rich flood of light that its

* See also Mylne, British Earthquakes, Edin. Phil. Journ. vol. xxxi.

laws, when once reached, must shed upon terrestrial physics. The period of mere cataloguing (like that of fossil-list making in the earlier geology) seems now past; we must give it up, and, in the words of Herschel, "we must now grapple with the palpable phenomena, seeking means to reduce their features to measurement, the measures to laws, the laws to higher generalizations, and so, step by step, advance to causes and theories." (Address, Camb. 1845.)

Many cases are recorded in the Catalogue of Earthquakes, of shocks occurring at two very distant places upon the earth's surface, but felt simultaneously, or nearly so, at both. The coincidence in time is, for all *very distant* places, rendered extremely doubtful, from errors of observation and of clocks, and of their reduction for difference of longitude when the places are not on the same meridian.

Milne also has collected several such instances; for example—

February 1750...England and Italy.
March 1750...England and Italy.
May 1750...England and Calabria.
August 1750...England and European Turkey.
February 1756.. England and Central France, Holland and the Rhine.
November 1756...Scotland and Malta.
January 1768...Shetland and Central England.
December 1789...Edinburgh and Florence.
February 1818...Great Britain and Sicily.
September 1833...England and Peru.
August 1834...Scotland and Italy.
September 1834...England and Peru.

In these, however, the coincidence in time cannot be assured within several hours; and it must be admitted, with Mylne, that the probability of anything more than mere coincidence is extremely slight.

In 1840–41 he found three shocks of this character: viz.

March 1840.........Scotland and Germany.
June 1841.........Terceira and St. Louis.
July 1841.........Scotland and France.
(Edin. Phil. Journ. xxxi. to xxxvi.)

A few such instances, that possess a closer approximation in time and some additional probability of actual coincidence, have been extracted from the Catalogue, and have been drawn in the diagram (Plate X *bis*) to scale,—those which had horizontal components of motion in the meridians N. to S. or S. to N. being placed at the right and left sides of the great-circle section of the globe; and those with horizontal movement E. and W. or W. and E., placed above and below.

Right lines connecting the supposed distant points of coincident shock by chords of the circle, would *probably* pass through the origin or centre of disturbance common to both places on the surface. The origin might be deeper to any extent, and *possibly somewhat* nearer the surface, at least in the cases of the longer chords. Were any reliance to be placed upon these coincidences, some of them would thus give a depth of origin of about 800 miles below the surface. None of those, however, that appear to have any satisfactory evidence of a real connexion in time and in origin, suggest a depth for the latter of even one-tenth that amount. All our other knowledge, both of seismic and volcanic phenomena, leads to the conclusion of foci very much nearer the existing surface; and the diagram may be regarded as conclusive evidence that these presumed coincident earthquakes at very distant points, even if proved simultaneous, are unconnected, and have different origins.

In the most singular case on record, that of Ochotzk and Quito, places nearly antipodal, the common origin would actually be in, or not remote from, the earth's centre; and it is not conceivable that the shock, which, if sufficiently powerful, must in such cases be felt nearly simultaneously over the whole globe, should have been confined to the two extremities of a single diameter.

In recapitulation, it may be convenient to give in *numbers*, for occasional reference, a few of the salient results of the distribution in time, already graphically discussed :—

	No. of Earthquakes.	No. of Years.
Total number of recorded earthquakes up to A.D.	58	1700
Total number from A.D. to end of the ninth century ..	197	900
Total number from the beginning of the tenth to the end of the fifteenth century	532	600
Total number from the beginning of the sixteenth to the end of the eighteenth century..............	2804	300
Total number from beginning of nineteenth century to the end of the year 1850	3240	50
Total Catalogue..............................	6831	

The number of great earthquakes (*i.e.* those, as already defined, in which whole cities and towns have been reduced to rubbish, many lives lost, &c.) have been but imperfectly exhibited graphically, and not at all for the later centuries, from their too frequent recurrence making their notation difficult or confused; they are here given numerically.

Number of great earthquakes from third century B.C. to beginning of our epoch	4
Number of same from A.D. to the end of the ninth century	15
Number from beginning of the tenth century to the end of the fifteenth century	44
Number from beginning of the sixteenth century to the end of the eighteenth century..	100
Number from beginning of the nineteenth century to 1850	53
Total	216

If we double the last number but one, to embrace the entire 100 years, the correspondence between the results for the two last periods is remarkably close, viz. 100 and 106,—and although the series is still an expanding one, yet as the numbers for the 16th and 17th centuries are not large; it is probable that for the last 150 years at least, our news of all *great* earthquakes have been complete, and the cataloguing of *them* perfect, showing that at present we may calculate upon 1·37—say 1·4, or nearly $1\frac{1}{2}$ recurrences of great and disastrous earthquakes every year, at some one or more places on the earth's surface, or one great earthquake disaster every *eight months.*

The total number of earthquakes, classed by months, is as follows:—

	Northern.	Southern.	Seasons, North.	Seasons, South.
January	627	19		
February	539	14		
March	503	9	1669	42
April	489	17		
May	438	20		
June	428	19	1355	56
July	415	18		
August	488	12		
September	463	17	1366	47
October	516	25		
November	473	32		
December	500	21	1489	78
Totals	5879	223	5879	223

Total of Catalogue for both hemispheres capable of mensual classification 6102
Total of unclassed, except as to annual date 670

Total number catalogued........ 6772

of which, there are recorded by season only—

Spring	6
Summer	7
Autumn	7
Winter	5
Total	25

January, February, and March have been taken for the spring of the Northern Hemisphere, and for the Southern, July, August, and September.

From the commencement of Catalogue to A.D. 1700, the recorded earthquakes in the northern hemisphere are to those in the southern, 940 : 21, or as 44·3 : 1. Again, from A.D. 1700 to 1800, the northern are to the southern, 1883 : 57, or 33 : 1; and from the year 1800 to 1850, or conclusion of the Catalogue, the northern are to the southern, 3076 : 145, or 21·2 : 1,—a further indication of the effect upon any such statistic record, of the march of human discovery, the last fifty years having brought into play the vast seismic regions of the Southern Ocean and South Pacific, before all but unknown. The observed earthquakes in the Southern Hemisphere may now be *estimated* at from 43 to 50 per century, or one every two years. (See Appendix, No. II.).

Distribution in space.

Such are, perhaps, all the legitimate conclusions that we can now come to on the distribution in historic time; and we now proceed to the discussion of the Catalogue, with respect to their distribution in space upon the surface of our earth. The method adopted, was that of graphically reproducing the area of each recorded earthquake by the superposition of coloured tints upon a large Mercator's map of the world. The map chosen for use was that arranged by J. Purdie, and published by Laurie, London, 1851,—the dimensions being 75 inches by 48 inches, which admitted, from its large size, of perfect clearness and accuracy in the laying down the most complex localities, and those in which the shocks are most numerous. This has been reproduced to a much reduced scale (Plate XI.), to accompany the present Report; but although executed with much skill and care, by the lithographer and engraver, I find with regret that its small size has rendered a perfectly accurate transcript of the original impracticable, and that a very imperfect notion of the latter is conveyed by the reduced map.

Strictly, the limits of every earthquake are completely indeterminate; and were our globe perfectly solid, homogeneous, and elastic, no limits but its own could be assigned to any shock from whatever centre originating. The practical limit (so to speak) is, however, where the movement has become insensible without instrumental aid; for such have been all the observations dealt with in our Catalogue. This frequently embraces enormous surface-areas; but these seldom, perhaps nowhere, are symmetrically posited round the centres, or presumed centres, of disturbance.

We are not concerned here with any of the smaller or local circumstances that modify, in different radii traced from any seismic centre, the effects, and the directions and distances, to which they are sensibly transferred, but merely with some of the greater and constant conditions (for the same region) in which some of the great natural features of the earth's surface permanently modify or limit the transference and area of transfer of earthquake-waves transmitted from adjacent centres. Thus, along the whole chain of the South American Andes, the propagation of shock is greatly more towards the west than to the eastward,—the highest crests and intermediate valleys forming a rude sort of limit, beyond which, to the eastward and into the heart of the table-land of the continent, shocks felt with destructive effect down to the shores of the Pacific are propagated with greatly diminished force, or rather are so felt upon the surface.

Again, to take another large example, the Northern Indian earthquakes, whose origin is in Nepaul and along the central Himalayan axis, are propagated southwards and westwards into the great plain of India, far more than northwards into the enormous mass of table-land of Central Asia. We are at this moment not concerned with the causes of this, but simply with the fact, that in these examples, and in several analogous instances, it is a matter of observation that certain great natural features of the earth's surface and material, do modify the forms of the surface-areas shaken, and render them unsymmetrical, shortening the radii in one direction, lengthening them in another; so that the area, which in a more homogeneous mass would approach a circular or elliptic form, tends to an elongated, linear, or irregular outline.

In laying down, then, the forms and sensible area of shock of each earthquake catalogued (and often necessarily, from the imperfect data alone afforded), the following rules were adhered to:—

1°. When the form and sensible limits of the shaken area were ascertainable from the narratives, they were adopted.

2°. When these were wanting, as in the great mass of cases recorded, then, as respects form, the physical, geological, or other conditions of each area, known to modify the distant propagation of shock, were attended to.

3°. As respects sensible area, when this could not be ascertained for any one diameter of the shaken area, from the narratives, certain arbitrary conventional rules (founded upon a natural basis, however) were resorted to.

The method of colouring therefore was this. The whole of the recorded earthquakes of the Catalogue were subdivided preliminarily, with as careful a judgment as possible, into three great classes :—

1°. Great earthquakes, being those in which, over large areas, numerous cities, &c., were overthrown; multitudes of persons killed, rocky masses dislocated, and powerful "secondary effects" produced.

2°. Mean earthquakes, or those which, although perhaps having a wide superficial area, were recorded to have produced much less destructive effects upon cities, &c., and little or no changes upon natural objects, and scarcely any loss of life.

3°. Minor earthquakes, limited to those which, although sensible and producing in their full development some effects (fissures, &c.) upon buildings, did not affect natural objects at all, and left few or no traces of their occurrence after the shock.

Of the first class, the great Lisbon shock of 1755 may be taken as a familiar type. Of the second, examples are frequent over Central Europe and the Mediterranean basin, Southern Asiatic Russia, &c. And of the third class we find notices almost daily from every quarter.

As respects the very smallest development of this class, namely, the continuous tremors of Comrie, Pignerol, &c. &c., they were grouped into single shocks upon the same method as described previously for their discussion as to distribution in time.

To distinguish these three classes upon the map, three different intensities of water-colour tint were prepared—all from the same colour (red ochre and Indian yellow). The first and most intense having been decided to designate the first class, that for the second was obtained of one-third the intensity, by dilution with three volumes of water; and the third by dilution of the second with three volumes again,—the intensities of the three tints being therefore as the numbers 1, $\frac{1}{3}$, and $\frac{1}{9}$, or 9, 3, and 1. A single wash or application of the tint relative to its class, upon the given locality, designated each earthquake when laid down on the map; and the *form* or *boundary* of the tint, when not to be had historically, being ruled by physical considerations as already briefly described, the *extent* or *superficial area* of the tint (when not derivable from the narratives), was arbitrarily fixed by the following rule :—

4°. The extreme radius of great earthquakes (1st class) was assumed equal to 9°, or about 540 geographical miles; that of the 2nd class at 3°, or 180 geographical miles; and that of the 3rd at a single degree, or 60 geographical miles.

These were determined from the consideration that our records give, when viewed with a broad glance and apart from physical and local limiting conditions of a powerfully disturbing character; *i. e.* when the area of disturbance has had a sensible surface-boundary approaching to an irregular circle or ellipse,—a sensible diameter of about 1000 to 1200 miles for great earthquakes, and about 400 for those of our second class, those minor ones of the third seldom extending to above 100 or 150 miles in diameter.

In the case of the enormous surface-areas of the first class, however, it has rarely been necessary, in the later years of the catalogue period, to make use of this convention at all, the historic boundaries being usually attainable. These in many cases comprise areas of surprising extent: thus the great Nepaul earthquake of 1833 extended sensibly over 7° lat. by

15° long., a surface four times that of Great Britain, and twice and a half that of France.

The Cutch earthquake of 1819 extended from E. to W. 5°, and from N. to S. 6°, though its dimensions in latitude are rather ill-defined. ('Asiat. Journ.' vol. xii. n. s.)

The Lisbon (1755) earthquake, and a few of those of the Malayan and Calabrian groups, and of South America, were sensible in certain surface-radii or great circles over 18°, or perhaps even 20°; but these are the extreme developments of our first class, and their limits historical, and therefore not affecting the preceding conventions. Some earthquakes recorded in the catalogue it was necessary to omit laying down upon the map at all, inasmuch as no sufficient data could be gathered to fix a probable local surface centre, nor any information as to the comparative energy of the movement. For example, some earthquakes (though but few) will be found catalogued as "in China," "in Libya," &c., with scarcely any particulars given. These omissions are not sufficiently numerous to affect the main result.

Besides these inseparable elements, volcanic and seismic phenomena, another intimately related phenomenon has been marked, as far as the data enable it. Those tracts of the earth's surface which have been presumed, with more or less probability, to be in slow process of subsidence to a lower level, are marked by blue tints, the boundaries of which are undefined to a great extent. These embrace the coral tracts of Darwin, the west coast of Greenland, and a small tract of the southern shores of the Baltic. All minor subsiding areas close to or in the midst of volcanic centres (such as the shore of Italy near Naples) are unnoticed, as such changes of level, due to the immediate action of adjacent valcanoes, are almost perpetual, and, in proportion to its state of activity, &c., common to every such area over the globe.

On examining the Mercator map (Plate XII.), then, upon which, subject to the above rules, the whole Catalogue has been graphically represented by tinting, it is to be remarked that—

1. The whole of the earth's surface known to be subject to earthquakes will be found tinted more or less intensely.
2. The most deeply tinted surfaces mark the places where either the number, or the intensity, or both, of successive earthquakes are the greatest.
3. Whether at any one point the depth of tint be due to number or to intensity, and the relation between these, may be found by reference to the Catalogue itself.
4. The shading-off or evanescence of tint towards the extreme sensible limits of the seismic (coloured) regions over the whole map is due (not to shading or evanescence of colour in the artist's sense, but) *to the superposition of tints only* upon the principles already explained. Hence it follows (admitting the two conventions made, as to intensity and area, and the partial extent to which these influence the results historically gotten), that the tinting upon this seismographic map does as truly represent, over our earth, the known seismic regions in form and extent, and the relative intensities and successive developments of seismic action therein, as the contour lines of a contoured map represent the forms of irregular surfaces, and the rate of inclination of the slopes and valleys by their approximation or separation; or as truly as (upon certain engraved maps, *e.g.* Irish Railway Commission of Ireland and some German ones) the relative heights and rapidity of rise of mountain chains are

graphically represented by multiplying the engraved lines that produce the shades (or tints) in the joint ratio of the heights and rates of slope, *i.e.* as the sines of the angles upon a given base.

I therefore venture to present this map as more than a mere picture—as being, in fact, a first approximation to a true representation of the distribution of earthquake forces, so far as they are yet known, over the surface of our world.

The volcanoes (including fumaroles and solfataras) are shown by black dots, and all that are known to be in activity, or are recorded to have been so, or from other evidence may be presumed to have been so, within the historic or late geologic periods, have been represented, from the authorities of Johnston, Berghaus, V. Hoff, Daubeny and others.

The exactitude of the number of volcanic vents along the great lines of foci, is, however, less important to our object than the marking in of isolated volcanoes.

Let us now examine our map in detail, and see what it can teach us, taking for the starting-point of our seismic survey the meridian of Greenwich, the central point nearly of the dry land, and passing eastward in our review. But first let us notice some points in the physical features of the earth's surface. Of the 111,000,000 of square miles of ocean (in round numbers) covering three-fourths of the surface of our globe, the greater part is to us a blank, so far as direct observation is concerned, the exceptions being the Atlantic with a part of the Southern Ocean from about 10° S., northwards, and of the Northern Ocean up to nearly 70° N.,—nearly all other marine seismic observations being in connexion with centres upon adjacent land.

We see these enormous pelagic areas, consisting of irregular, saucer-shaped, shallow depressions, bounded by flowing coast-lines which, by the connecting points of oceanic banks and islets, we can generally unite into closed curves, forming thus distinct but inosculating basins—of which the Northern and Southern Pacific together form the largest example. Those vast but comparatively very shallow depressions may, when viewed in individual detail, be subdivided into smaller shallow concavities by banks and shallows below the ocean surface. But each great oceanic saucer, bounded by the existing continents and their fragmentary outliers, presents an almost continuous fringe around, of mountain-chains and volcanic foci. Thus, starting from Mount Elias, long. 141° W., lat. 60°, at the northern extremity of the Pacific, we find a scattered chain of volcanoes along the west coast of North America, with a continuous bounding coast line of mountains. South of the gulf of California, the Mexican and Central American volcanoes, with those of the South American Andes, carry on a closely linked chain, almost to its southern extremity. Here the volcanoes of Tierra del Fuego trace the line on towards that of Graham's Land, where it plunges into the unknown regions of the Antarctic continent.

Returning to the extreme north again, from Mount Elias, we have the almost unbroken line of mountain and volcano of the Aleutian Archipelago; carried down through the great elevated peninsula of Kamtschatka, the Kurile Isles, Jesso, Japan, the Philippines; and to the north of New Guinea by its volcanoes and those of New Britain, the Solomon Isles, Egmont, New Hebrides, New Caledonia, and New Zealand, to the Antarctic ice again at the Balleny Islands and Buckle Volcano—a connected belt, with the exception of the unknown Antarctic region, round its vast pelagic circuit. Within this the subordinate or secondary basins are marked, though less distinctly, by lines of volcanic foci: thus from Japan to New Ireland through the Ladrone Islands, a distinct though sparse line of volcanoes cuts off the basin (nearly one-half the area of Africa) bounded on the north by Japan, and on the west by the Philippines.

From lat. 30° S., a sub-oceanic crest-line of shallows appears to spur off eastward from the volcanic foci of New Caledonia and New Zealand, and, trending westward and a little northward through the Tonga, Society, Marquesas, and Gallapagos Islands, connected by continuous banks, joins the Central American group of volcanoes, thus cutting the great ocean basin nearly into two secondaries, each of which is probably in a less marked manner subdivided,—the northern sub-basin, by a line through Christmas and the Sandwich Islands, to some point of the volcanic group of the Andreanofsky Islands in the Atlantic Archipelago, making in its course a wide sweep to the east and north through an almost continuous chain of isles and banks; and the southern sub-basin by a line from the Society Islands through Easter Isle and Juan Fernandez, and combining with the great Chilian volcanic chain at its eastern extreme.

A vast fissure (noticed by Humboldt), and marked by an almost continuous line of volcanic vents, extends in a direction nearly east and west, right across Mexico, between lat. N. 18° and 19°. It is nearly 500 miles in length. Its main direction, if produced, bears upon the volcanic island of Revillegigedo, and, as Humboldt also thinks, probably extends to Mouna Roa, in the Sandwich Islands. The Mexican extremity of this enormous crevasse probably marks the continental end of one of the great dividing ridges of the sub-basins of the Pacific.

Within the great Pacific Basin will be found (tinted blue) most of those great areas of probable subsidence indicated by Darwin*. These bands will be observed occupying the great sub-basins of the ocean, not very distant from great volcanic lines, and although not (with our present imperfect knowledge of soundings) quite free from the suspicion of occasionally intersecting such lines (*e. g.* Marquesas and Society Islands, Ladrone, and New Guinea), yet, on the whole, keeping surface positions intermediate to the volcanic cinctures adjoining or around them.

Less distinctly we may trace the cincture of mountain- and volcanic chain around the shallower Atlantic basin, and, through it, upon the submarine elevations dividing its sub-basins. Thus, starting from Iceland; the Ferro Isles, Scotland, and the mountains of Wales and England (with the breach of the English Channel, a narrow line in relation to the scale of our present survey), the Rhenish-German chains, the French and Western Alps, the Pyrenees, to Cape Finisterre and the coast of Portugal, connect by the Azores, and by innumerable submarine rocks and shoals, across to Newfoundland. Here the lines to the northward may be pronounced unknown, until, returning back to Iceland, we find it approximates to the point we left through the great igneous and abrupt coast-line of Greenland.

In connexion with this oceanic basin, we have two probably subsiding tracts of land—the one in Davis's Straits, the other in the Baltic—both tinted blue.

The Central Atlantic forms a well-marked basin girded with volcanoes and mountain-ranges. Leaving the last stated boundary-line at Newfoundland, and going again eastward to the Azores, thence through Madeira to the Canary Isles, the Cape de Verds and including the great sub-oceanic volcanic region between 15° and 30° long. W., and lat. 3° N. to 10° S., going westward by the island of Fernando Noronha to Cape St. Roque on the extreme east of the South American continent, returning to Newfoundland,

* See Dana on Areas of Subsidence in the Pacific. Ass. Amer. Geol., Albany, 1843, and Edin. Phil. Journ. (New), vol. 35. p. 341.

we trace the line southwards through the several chains of the United States down into Georgia, where, with the comparatively narrow breach of Lower Florida, it is carried on by Cuba and the whole chain of volcanic islands of the West Indies to Trinidad and the South American continent again. The Gulf of Mexico and Caribbean Sea form a smaller but separate basin. In the southern Atlantic we can trace a dividing ridge through South Ascension—the great suboceanic tract just referred to—North Ascension, St. Helena, and probably to Cape Negro on the African west coast, and thence to the Cape of Good Hope, and returning westward by Tristan d'Acunha, thence S.W. to the Isle of Georgia (lat. 55° S.) and through the Falkland Islands to the volcanoes of the southern point of South America; but this, like the sub-basins, through the scattered indications which alone we yet have in the vast southern portion of the Eastern or Indian Ocean west of Australia, is uncertain.

There is little doubt that Australia, on its northern existing coast-line, was once united with New Guinea and the Aru Islands west and south of it (Wallace, Silliman's Journal, vol. xxv.), and possibly with much of the land outlying to the west of that vast and now isolated continent; if not, the intermediate seas would be much deeper than they are, and the west coast of Australia with its mountainous chains would bound an ocean basin whose western boundary would be marked by a line of volcanoes from New Guinea to New Zealand and the Southern Sea.

The seas of Ochotsk, of Kamtschatka, of Japan, and, above all, the Chinese and Malayan Seas with Borneo in the midst, form so many distinct basins, small relatively to the vast areas we have been reviewing, but distinct and strongly marked. In the Chinese Sea we have a probable tract of subsiding land, tinted blue upon the evidence of Darwin. The bay of Bengal, well-marked all round northward from Sunda, and belted with volcanoes to the Ganges, and with mountains near the coast thence to Ceylon, joins probably Western Australia by a suboceanic ridge, indicated through the rocks of Greville and Compton, the Island of Apaluria with the adjacent submarine volcano of 1789, and the ocean shallows and soundings, about 100° W. long. and 20° to 25° S. lat.

The separate basin of the Arabian Sea is equally distinct, from Cape Comorin along the Malabar coast, all highly mountainous, Beloochistan to the mouth of the Persian Gulf (itself a small basin), thence by the Arabian coast-line to the volcanic region at the mouth of the Red Sea, and into Abyssinia with its characteristic and enormous crater-form lake of Tzana (though as yet not possessing any earthquake record), and thence through regions scarcely known upon the East African coast, crossing to the Comoro Islands (volcanic) and to the mountainous regions of Madagascar,—the volcanic islands of Bourbon, Mauritius and Rodriguez, the Nazareth and Saya banks, the Chagos Archipelago and the Maldive and Laccadive Islands, completing the cincture with the Malabar coast again.

Along the great band of these islands, and thence trending westwards by the Saya bank, lies one of the great tracts of ocean-floor which Darwin has shown to be probably subsiding (tinted blue). Assuming that this really is a band of subsidence, it would be more probable that the volcanic girdle takes a wider sweep to the south and west of this band, and, leaving the Island of Rodriguez, makes for the volcanic centre marked in the ocean at long. 90° E., lat. 10° S., and thence turns northward to join Ceylon, Cape Comorin and the volcanic region of Pondicherry.

Leaving the great ocean and great continent, we trace smaller basins (or rather saucers, for their extreme shallowness in relation to their surface-area must never be lost sight of), where larger portions of the elevated mountain-cincture, studded here and there with volcanic vents, are found unsubmerged and inland (*i. e.* where the basin within its boundary is partly land and partly water), thus: Ætna, Lipari, and Vesuvius, the Apennine chain, the southern and western Alps, the Pyrenees, and the great tableland and axial chains of the Spanish peninsula, with the mountains of Northern Africa, on through Pantellaria and Sicily, form one such basin. Closely connected with this is the adjoining basin of the Ægean with the volcanic Greek Islands: the Black Sea, with the volcanic regions of Armenia and the Caucasus, form a distinct basin extending on the north far into Russia; the Caspian, with the Sea of Aral and the plain of Tartary embracing Persia, another, having its own volcanoes near the former sea, while Central Asia, so little known, seems probably divisible into several vast saucer-like areas, north of the great tableland, of which the great lakes and the Altaï chains, with their imperfectly described volcanoes, probably mark some parts of the cinctures, but which, in the absence of knowledge as to relative level, it would be premature to attempt to trace. Many of these basins further on to the north appear no longer bounded by closed curves upon land, but to open out along the great river-courses which run northward and become lost to our knowledge in the icy solitudes of northern Asiatic Russia.

Northern Europe presents us with the great Scandinavian, German, and Russian saucer, whose features have been made so clear to us by the labours of Murchison and others; while, further north and west, a distinct oceanic basin appears in the Northern Sea, of which the Norwegian chain, Shetland, the Ferro Islands, Iceland, the west coast of Greenland, and the volcanic islands of Jan Mayen, are the marked boundaries.

North America, so far as its surface has been ascertained, is divisible into several well-marked shallow basins, the most obvious being those of the Mississippi; of the Arctic Highlands; the two deserts east and west of the Rocky Mountains (lat. 30° to 40° N.); and of the great lakes, to which may be added hereafter Labrador and the North of Canada with Hudson's Bay; the eastern talus of the great Atlantic slope falling into the boundary of the Atlantic basin. Enough, however, has probably been stated to indicate that, viewed upon the broadest scale, the surface of our globe consists, as respects its present solid surface, of a number of saucer-like depressions, when large, having also *convex* central areas, all having plan outlines approximating to extremely irregular ovals or other closed curves, and bounded by mountain-chains or mere rounded or flat-topped ridges or elevations of the solid sphere, greater or less. Where three or more of these inosculate, the point between the junction is most frequently a group of mountains or a high tableland, or both,—as, for example, the knots (Cusco and others) of the South American Andes, upon which the suboceanic ridges abut. The greatest of these saucer-like concavities either form or subdivide the beds of the ocean, but other such shallow basins can be traced upon the existing land, and embracing seas or parts of seas, or great lakes, or river-courses within them, but still enclosed by girdling chains of mountains or the precipitous flanks of tablelands, which latter in their full development are the pedestals of the greatest mountain-chains. Amongst the wide-sweeping curves that indicate the dividing crests (if we may use such a word to designate elevations often, *especially in the subdividing ridges of the oceanic sub-basins*, so very low in relation to the areas they separate) of these vast oceanic basins, it appears impossible to trace any approach to parallelism, or, indeed, that such an arrangement could exist.

We do, however, remark, that it is along these girdling ridges, whether mountain-ranges or mere continuous swelling elevations of the solid, which divide these basins beneath the ocean surface one from the other, that all the volcanoes known to exist upon the earth's surface are found, dotted along these ridges or crests in an unequal and uncertain manner.

And as our oceans and greater seas are bounded, and below their water-surface subdivided, by these ridges, along the lines of which the volcanic foci are found; so, as long observed, it is a fact that all active volcanoes are comparatively close to the sea, or to some large body of water; indeed, they could not present the phenomena they are known to do, without a supply of water, and nearly always of sea-water, more or less constant and plentiful, derived from this propinquity. (See Trans. R. I. Acad. vol. xxi. pp. 98, 99.)

However different, then, may have been the train of forces upon which the elevation of the mountain-chains and other relatively raised lines of the present surface have depended, from those which now produce the ejections thrown up by volcanic action, the latter seem to follow upon the traces of the former; and we shall find that the earthquake generally does so likewise. The distinction long made, into linear and circularly grouped or clustering volcanoes, I conceive has no foundation in nature. By far the largest proportion of all the volcanic vents over the whole earth are found arranged along the flowing lines of mountain-chains.

The so-called clusters or *circular* groups never are found covering surface-areas larger, if so large, or more widely apart, in any single group, than those within which volcanic vents are found that undoubtedly belong to linear arrangements (Mexico for example).

Nearly all the clusters or circular groups of volcanoes are situated in the ocean, and far from continental land; they stand on, and are connected with each other, by oceanic plateaux, rounded submarine ridges, shallows, rocks, and islands, and by similar connexions with points of continental coasts, either mountainous or volcanic. The conclusion seems justifiable, that these clusters or groups are the only visible points, "few and far-between," situated along sub-oceanic linear volcanic ranges, along which the open vents are probably much fewer than along equal lengths on land, but still marking as truly as the most thick-set linear vents the great lines of fracture of the earth's crust. Were this the proper place, much might be adduced in support of this view of volcanic distribution.

The connexion between volcanic and seismic effort is so obvious, although the nature of their connexion has been so little understood, that we are prepared to find the deepest tints of the seismic map fringing off from those great mountain-ranges where the volcanic foci stand close in rank; but it was not before so apparent that, along the elevated ridges or mountain-ranges that gird and divide the great surface-basins, even when not volcanic, or when volcanic foci are rare and widely separated, the earthquake is still found to range in broad bands, following the general line of the crest.

Upon a very much minuter scale of survey than we are now occupied with, such would seem dependent upon the physical fact, that the earth-wave will be best and furthest propagated through the most solid and elastic line of material, that is, in the axial line of mountain-chains and valleys, as is found to be the case; but the indication of our map is a far more extensive one, and points to some different and deeper cause. Thus, to resume our seismic survey of the Map, Iceland, Ferro, Shetland, and the south-west coast of Norway, nearly to Christiania, form a broad band of seismic connexion, which would probably run on to Greenland, and along its coast to Jan Mayen, did we know anything of their earthquake history.

The fact (if it be so), that the west coast of Greenland, in Davis's Straits, is sinking gradually, would in nowise conflict with the probability of seismic action, or even elevation of the opposite eastern coast, which, it is extremely probable, may be slowly rising, just as the Scandinavian peninsula is doing; and it does not seem a disproportioned supposition, that all three changing levels are due to the prodigious scale of volcanic action going on at Iceland.

The Swedish system is another band stretching north-west from the great lakes to Kola Bay in Russian Lapland; and future observation may probably include in it the parallel chain of the Doffrefels Mountains. To the south we mark the broad band whose extremities are Portugal and the Azores, always in seismic sympathy with each other, and with which the band of the Canaries is in relation through Madeira, and is also more distinctly connected with the earthquakes of Barbary and Morocco.

From Tunis, a narrow but intensely marked seismic band stretches up through Sicily and Italy, sends off a spur to the west through the Alps of Piedmont and Southern France, along the whole line of the Pyrenees, and to the northern coast of Spain; and widening out over the central Alps, so as to cover a large area of central Southern Europe: extending east and west from Lyons to Vienna, it again contracts in width at about the latitude of Strasburg, and stretches away northwards over the whole Rhenish mountain system, and becomes nearly evanescent upon the low plains of Holland and the coasts of the North Sea, where, though infrequent, earthquakes are not unknown.

Over the great plain of Central Europe, and far into Southern Russia to the north of the Euxine, the want of observations with distinct dimensions renders any attempt at precise boundary nugatory. Were our records better, the Carpathians would no doubt stand out in stronger tint than the well-inhabited country of Poland and the Vistula, where the greater frequency of seismic records deepen the tint from Cracow up towards Riga. Better observations would no doubt also mark with a deeper tint a band of connexion along the Balkans and line of the Danube, between the Austrian Alps, so frequently shaken, and the Bosphorus, where the neighbourhood of Constantinople shows itself abnormally intense, from the reiterated records of earthquakes there that have been collected century after century at that ancient seat of splendour and civilization. Thus it is that the disturbing causes that we have remarked as affecting the Catalogue follow into its discussion in space as well as we have seen they do into that of time.

A broad but somewhat ill-defined seismic band stretches from the Greek Archipelago to Constantinople, spreads over a large portion of Asia Minor, and is carried through Palestine, on to the valley of the Lower Nile and the coasts of the Red Sea, extending further south along its Arabian shore. From the Gulf of Scanderoon, by Aleppo and Mosul to Lake Van, and the south of Ararat to Shirvan and Baku upon the Caspian, a wide band of great and long-continued energy extends, which probably joins into the Caucasus and is connected with the seismic system of the Ourals in the distant north.

Again, from about the parallel of Bagdad, a broad but ill-defined seismic band stretches nearly due east through the whole of Persia, Khorassan, and to the Hindoo Koosh, sending off a narrower band along the shores of the Persian Gulf. About Cabool the Persian band joins into the vast seismic area of Northern India—a band, whose northern boundary is the Himalayan chain, and which stretches nearly parallel to it from Cabool to Calcutta and to the Gulf of Cutch. Beloochistan appears exempt, but probably only because hitherto without observation or record. Leaving the vast and strongly agitated seismic system of Central Asia, of the boundaries of which so little is yet known beyond the general fact that northwards the seismic bands appear to follow the great river-courses, or more probably the great axes bounding *them*,—and passing also the so frequently convulsed Chinese empire, which appears to have two chief seismic centres about Pekin and Canton (these cities have been the *centres of observation* for all, or nearly all, the Chinese records of earthquakes that we possess, and hence one reason of the depth of seismic tint around them; but it is also to be observed that two of the great volcanic districts of the "Fire Hills and Fire Wells" of China are situated within the tinted or shaken regions adjacent to the two capitals), with a third more central volcanic region, of which I am not aware that anything is known seismically,—and remarking the apparent exemption of Cochin China, for which there are no records,—we at length arrive at the greatest and most formidable earthquake- and volcanic region upon our globe. Stretching in a vast horse-shoe, convex to the south, from Burmah and Pegu, and surrounding the great island of Borneo, with an intervening belt of sea, and reaching round to Formosa on the north-west, we have an almost continuous girdle of volcanoes and lofty mountains. Every island of the group, including Java and Sumatra, Celebes and Mindanao, is shaken with earthquakes the most formidable and frequent; and we can point to no spots upon the whole earth's surface upon which seismic energy is exhibited with an intensity equal to that of Luzon and Sumbava.

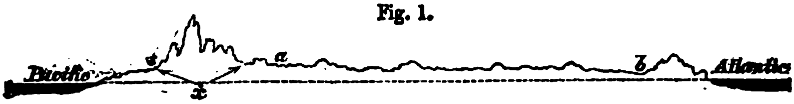
Nothing even in South America or Mexico appears to rival the grandeur of volcanic energy and resultant seismic action here. In 1815 the thunderings of Tomboro, in Sumbava, were heard nearly 1000 miles away (through the earth no doubt). The ashes, or, more correctly, the finely-divided tufa-dust, floating in the air, made mid-day into darkness 300 miles away in Java, and were precipitated at sea even a thousand miles from the point of ejection, while whole tracts of country, with inhabited towns, have suddenly become engulphed and disappeared during periods of eruption, which over a large portion of the chain, from one extreme to the other, are almost continuous.

It will be remarked that the seismic tint is both more intense and relatively *more circumscribed in area* along the bands that surround the linear volcanic vents, where they cluster thick, than along mountain-chains or ridges that possess few or no volcanic vents. This no doubt arises from the centres of impulse in active volcanic lines being situated at a comparatively small depth, in fact, coming from the actual bases of the crater, or not far beneath; and hence the horizontal propagation is not so great for a given force of impulse as where its centre is situated deeper, and the explosive effort rendered abortive to rupture the solid crust above. The intensity of tint in the former case is due to *repetition* of effort, as well as to occasional intensity of impulse.

An earthquake in a non-volcanic region may, in fact, be viewed as an uncompleted effort to establish a volcano. The forces of explosion and impulse are the same in both; they differ only in degree of energy, or in the varying sorts and degrees of resistance opposed to them. There is more than a mere vaguely admitted connexion between them, as heretofore commonly acknowledged—one so vague, that the earthquake has been often stated to be the *cause* of the *volcano* (Johnston, 'Phys. Atlas,' Geology, p. 21), and more commonly the volcano the cause of the earthquake, neither view being the expression of the truth of nature. They are not in the relation to each other of cause and effect, but are both unequal manifestations of a common force under different conditions.

Further north we have the somewhat less terrible, but yet deeply-coloured seismic bands of Japan, the Kuriles, and Kamtschatka; and, passing to the opposite shore of the Pacific, we are presented with the deeply-coloured seismic bands of Mexico and the South American Andes, whose influence reaches far out into the ocean, but eastward or landward is checked by the great chain. The reason of this fact, which has been before alluded to, is not hard to find. The general *section* of the South American continent, from west to east, consists of a comparatively low-lying narrow littoral border-country on the Pacific; then the immense chain of the Andes rising in successive ranges to the axial peaks, and beyond these a vast plateau—the elevated land of the great continent—reaching over to near the western coast, where some lower ranges of mountains terminate the Atlantic shore and bound its basin. This is rudely shown in the accompanying figure (1).

Fig. 1.



Now if a shock be transmitted from any origin within the great chain, and below the level of the great tableland, *a b*, as from a point *x*, the transmitted elastic wave in the direction *x s*, reaching the surface after a very short transit, will, in accordance with the well-known law of elastic bodies, have its amplitude increased (just as the last billiard-ball of a line of touching balls, is that which is projected when the first of the line is struck by the blow of a propelled ball), and more powerfully shake all surface-objects at *s* than others situated at *a*, although at an equal radial distance from the centre of effort,—the free movement of the elastic wave being here reacted upon by the elastic mass of the tableland which blocks its way until compressed. Objects on the tableland, at an equal distance from the origin, may (dependent upon its depth) receive the shock (even if of only equal amplitude) at such an angle of emergence as will give a less power of overthrow to the horizontal component of the wave's transit. There will in every case be a reflected wave back from the mass of the tableland—an *earthquake echo*—producing at *s*, or along the littoral border, a second shock, with a line of direction nearly the same, but with a direction of motion reverse to the first, one shock only being felt on the tableland.

To return, the seismic band of the Andes, at the extreme north of the continent, and at Trinidad, inosculates with that of the West India Islands, which sweeps round the Caribbean Sea, and appears, so far as records go, to transmit its movements further into the Atlantic, than into the former sea; if so, that probably arises from causes quite analogous to those already explained for South America—a shallower sea-bottom to the westward, on the Caribbean Sea, thus playing the part towards the deeper bottom of the Atlantic that the tableland plays towards the littoral slope of South America. The North American records have been too few and ill-defined as to boundary to produce as yet any very distinct conclusions from the tints, which prove, however, that its western and southern seaboard are by no means free from earthquake. This has in great part arisen from the great want of orographic delineation on nearly all (even the largest and best) maps of the United States, which omit all heights and natural features. The Californian system west of the Rocky Mountains, that of Upper Missouri, of the Mississippi, and that of the northern lakes and basin of the St. Lawrence, form the chief and separate regions in which earthquakes have been so far observed most frequently.

Future observation will probably show a connexion between the great sub-oceanic seismic tract of the South Atlantic and the South American continent on its western sea-board, between Cape Roque and La Plata. It does not appear so far to have any connexion with the opposite African coast between Cape Palmas and the Bight of Biafra. A better knowledge will also probably widely extend the seismic boundary of the Cape of Good Hope along both the east and west shores of Africa to the northward, and bring within it the great island of Madagascar, as to which nothing is so far known. New Zealand (unhappily for its future progress) will afford one of the best regions in the world for the study of volcanic and seismic phenomena in their connexion.

The earthquake-band of Western Australia, at present so small in proportion to its vast surface, will probably be found to reach much further towards the interior, and embrace Van Diemen's Land and a considerable stretch of the southern coast to the eastward. It remains yet to be observed whether even the small surface explored of the east side of the Great Island is subject to earthquakes or not. Abyssinia too, though not affording the record of a single earthquake, is too closely united with the seismic region of Arabia and the mouth of the Red Sea, to be probably perpetually in repose.

There are great *untinted spaces* upon our map. The northern and southern polar regions, immense tracts in North America and in Northern and East Central Asia; surfaces in South America nearly as large as all Central Europe; the whole African continent except the northern edge and southern point; nearly the whole of Australia, and almost the whole of the bed of the great ocean, are perfectly unstudied and unknown to us, as respects their seismic condition. They appear white, and hence free from earthquake, upon the map, but only because there are no observations.

Future researches will probably, however, show that all these vast tracts of land are traversed by earthquake-bands presenting generally the features that we recognize elsewhere, and that the ocean-bed, far from the continents, although always much less disturbed, for equal extent of surface, than the land, and especially than the coast, of the great oceans, is also traversed by earthquake-bands continuous with and tracing out their shallowest contours.

Had navigation been, in times past, as frequent and constant in the Pacific and Southern Indian oceans as it has been in the narrower Atlantic, especially north of the equator, the former would most probably present, over very much of their vast surfaces, light seismic tints such as almost the whole Atlantic presents, included as it is within the range of movements transmitted from both its western and eastern borders, and also from the foci within its bosom, connected by seismic lines so closely adjacent, *i. e.* with sub-basins so comparatively small in area.

Imperfect as are our observations on land, they are much more so upon the surface of the great ocean that covers three-fourths of our globe; so that only a very rude approximation, and from very partial data, can be made towards the solution of the question, What is the relation of seismical energy beneath the land and the ocean?

The result of Perrey's, memoir 'On the Basin of the Atlantic,' (Dijon Mém.) assigns, for a period from 1430 to 1847, or 417 years, a total of only about 140 shocks (or three shocks per annum) observed over an area of about 24 millions of square miles. If we contrast this with the only tolerably well-observed portion of the dry land, the great European area, we find thereon at the least 40 shocks per annum observed upon an area of 1,720,000 square miles, or (allowing for regions included, but never observed), say, 1,500,000 square miles. There occurs therefore annually in the Atlantic basin one shock for every 8,000,000 square miles of surface, and, in the European area, one shock for every 37,500 square miles of surface; so that within these large areas the seismic energy beneath the land is to that beneath the ocean-floor as 213 : 1 nearly. The annual number of observed European earthquakes is certainly below the actual number that occur; and although the Atlantic is the only oceanic surface of our globe over which there can be a pretence even to correct observation, yet its recorded numbers must be very far indeed below the truth, and immeasurably lower in proportion than for Europe. Making, however, every allowance for imperfect information in the pelagic area, the disparity of relative numbers is such, as to warrant our estimating, with some confidence, that the seismical energy is manifested with much greater power for equal areas upon the dry land than upon the ocean-bed.

Should it ultimately prove a fact, as rendered probable from the beautiful investigations of Darwin, that there are great areas of gradual subsidence now in motion beneath the Pacific, it may still happen (though it is not probable) that seismic or even volcanic bands may traverse such areas of subsidence, without materially affecting their general downward movement. Although many portions of the earth's surface now show evidences of vertical instability, either slowly, or *per saltum* occasionally, rising or sinking, these effects are all comparatively insignificant in extent. The great formative forces, whatever they were, upon which the elevated land of the great continents and the depression of the ocean-beds depended, have ceased sensibly to act. The function of the volcano and the earthquake in the existing cosmos is not creative, but simply preservative; and vast as they appear to eye and sense, their effects are very small in relation to the totality of the great terrestrial machine.

If, however, such large areas of oceanic subsidence as have been supposed really exist, they will most probably be found situated almost centrally within the oceanic sub-basins, and hence surrounded but not traversed by seismic bands.

There is one fact, which is shown by the relative positions, upon this map, of the greatest volcanic areas upon our globe (and these the most active) and of the blue-tinted areas of probable subsidence, that is worthy of fixing our attention.

It will be observed that the blue bands of probable subsidence are tolerably adjacent to the greatest seats of volcanic activity, and that the latter generally have subsiding areas at more than one side. Thus, in the Pacific, the blue band is along the great volcanic girdle from Celebes to New Zealand, and thence stretches between (and at one point *may* cut through) the line of suboceanic volcanic girdles, from the New Hebrides to the Marquesas.

Again, the great volcanic horse-shoe girdle of Sumbava is between the blue (subsiding) area in the China Sea north of Borneo, and the blue coral bands north of Australia, which whole continent, or at least its western and northern parts, may probably be subsiding also. Lastly, in the north we have Iceland and its volcanic system, between the sinking coasts of Greenland and those of the Baltic.

If we admit, then, as certain, that these vast tracts are subsiding, we can scarcely withhold our belief that the subsidences are due to and are the equivalent in bulk of the solid ejecta and exhalations of these various great volcanic areas respectively.

The assumed area and extent of subsidence of those supposed subsiding tracts are, however, I apprehend, greatly overrated; this, however, is not the place to pursue their consideration.

From all that has preceded (here and in former Reports), it is plain that nothing like one or more great general horizontal directions of seismic movement can exist upon any very large tracts of the earth's surface; and that if it be even possible to assign, as proposed by M. Perrey, a general horizontal component for limited areas, the method does not admit of extension. The normal type of an elastic wave in a homogeneous solid, is only varied, so far as observation yet goes, by the accidents principally of material and surface, whether the area of disturbance be great or small.

Nor does the seismic intensity in any part of the world, so far as originating impulse is concerned, seem connected with the superficial character, to the greatest known depth, of the geologic formations, beyond what connexion is necessarily inferential from the seismic bands (where they exist) following, on the whole, the lines of mountains and ridges that separate the surface-basins of the earth, whether volcanic or not. While, therefore, the seismic waves diverge, from axial lines that are generally of the older rock formations, and often of crystalline igneous rocks or actively volcanic, they penetrate thence formations of every age and sort, even to plains of the most recent post-pleistocene clays, sands, and gravels; and occasionally, by the secondary efforts of great shocks, these loose materials are shaken or caused to slip and gather up into new forms (as in the Ullah Bund at the mouths of the Indus, &c.), and so the earthquake has come to be mistakenly viewed as a direct agent of elevation. Its true cosmical function is the very opposite: it is part of the dislocating, degrading, and levelling machinery of the *surface* of our globe, while the part of the volcano is restoration and renewal. Both are, however, not creative but conservative (strange as it may sound), and suited to the period of man's appearance and possession of the earth.

Viewing as a whole, and in a single glance, the distribution of seismic energy over the whole globe, it presents (so far as we yet know) a vast loop or band round the Pacific, a more broken and irregular one around the Atlantic, with subdividing bands and a vast broad band stretching across Europe and Asia, and uniting them.

Thus an apparent preponderance of seismic surface seems to lie about the temperate and torrid zones, both northern and southern; but extended observation is yet required in high latitudes, and particularly in the Antarctic ones, before we dare venture to affirm that there is a real preponderance extending over any one or more great climatic bands or zones of the earth's surface.

The following are perhaps the most general conclusions that are at present justifiable:—

1st. The superficial distribution of seismic influence over existing terrestrial space does not follow the law of distribution in historic time; it is not one of uniformity. There is this resemblance, which, however, is not a true analogy,—that as the distribution is paroxysmal in time, so it is local in space.

2nd. The normal type of superficial distribution is that of bands of variable and of great breadth, with sensible seismic influence extending from 5° to 15° in width transversely.

3rd. These bands very generally follow the lines of elevation which mark and divide the great oceanic or terr-oceanic basins (saucers) of the earth's surface.

4th. And in so far as these are frequently the lines of mountain-chains, and these latter those of volcanic vents, so the seismic bands are found to follow them likewise.

5th. Although the sensible influence is generally limited to the average width of the seismic band, paroxysmal efforts are occasionally propagated to great superficial distances beyond it.

6th. The sensible width of the seismic band depends upon the energy developed, and upon the accidental geologic and topographic conditions at each point along its entire length.

7th. Seismic energy *may* become sensible at any point of the earth's surface, its efforts being, however, greater and more frequent as the great volcanic lines of activity are approached.

8th. The surfaces of minimum or of no known disturbance, are the central areas of great oceanic or terr-oceanic basins or saucers, and the greater islands existing in shallow seas.

The fact that certain low-lying river-basins, such as the Mississippi and the Ganges, are the seats of earthquake disturbance, does not conflict with the last proposition. In these cases, the impulse is propagated into the plain from the band of the bounding ridges; and when these are very large in relation to the basin, the breadth of the seismic band may overlap its whole surface,—as for example in the basin of the Ganges, where the seismic banks of the Himalaya and Vindhya mountains cover the whole plain of Northern India.

We have thus extracted all the information that our Catalogue, or indeed any further cataloguing of earthquakes, seems capable of giving us; future research must take a more distinctly physical character. I therefore proceed to some observations upon instrumental seismometry and the construction of seismometers, upon which our future progress must much depend.

Twelve years ago, at the period of the author's paper (Trans. R. I. Acad. vol. xxi. 1846) "On the Dynamics of Earthquakes," the construction of seismometric instruments appeared a comparatively easy matter; there did not seem to be much difficulty in producing even a self-registering instrument that should give every element of the earth-wave at the surface, whose normal velocity of propagation was then assumed to be extremely great, to approximate to that theoretically due to the elasticity of solid rocky media, and not to vary very materially in direction of propagation during its transit from the origin, to any distant point of the earth's surface.

It is only at a very recent period that experiments and observations as to the actual phænomena, the velocity and direction of shock, &c. have begun to show the real difficulties of the subject; and as these are apparently not very generally recognized, I propose pointing some of them out here, prior to indicating the limits within which for the present, it appears to me, we must be content to restrict our seismometric aims and instruments, and describing what form of instrument, and in what localities placed, would appear, with our existing knowledge, the best to give us some information—approximate only, and incomplete without doubt, but yet such as can be made a safe basis for a future higher step with more refined and comprehensive instruments. I shall avoid as much as possible (as out of place in this Report) any mathematical treatment of the subject. The antecedent history of seismometers is in brief as follows:—

All the instruments hitherto devised or set up may be divided into two great classes:—1, *observational*, those whose motions must be observed and recorded after each shock; 2, *self-registering*, which record their own past movements however repeated, and admit of their observation at any subsequent period within certain limits. Each of these classes is again divided into two sorts:—*a*. instruments dependent upon the movements by displacement of liquids; *b.* those dependent upon the partial displacements of solids. Of the first class, there have been—

1 (*a*). That of Cacciatore of Palermo, long in use in Sicily. It consists of a wooden circular dish about 10 in. diameter, placed horizontally and filled with mercury to the brim-level of eight notches that face the cardinal points and the bisecting rhumbs between, and are cut down through the lip of the dish, equally in width and depth all round. Beneath each such notch a small cup is placed, to receive such mercury as may be thrown out of each notch by an oscillatory displacement of the main mass of mercury, due to a general oscillation of the whole system. Either the volume or the weight of mercury found in each cup is supposed to measure the value of the displacement, and hence of the shock in its direction in azimuth.

2 (*a*). The wooden or other bowl of molasses, or other such viscid liquid, suggested for use by Mr. Babbage.

3 (*a*). A cylindric tub with chalked or whitewashed sides, and partially filled with some heavy and permanently coloured liquid of deep tint. (Mallet, Admiralty Manual, sect. vii. p. 218.)

4 (*a*). Tubes partially filled with mercury, ⌊__-shaped, with the horizontal and open limbs directed to the cardinal points, for the horizontal component of shock; and U-shaped for the vertical component,—both sets being provided with marking indices, to show previous displacement of the mercury. (Mallet, Admiralty Manual, sect. vii. p. 214.)

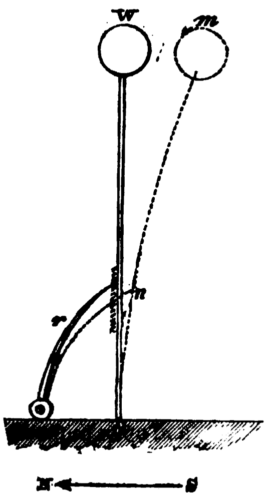
5 (*b*). The oldest, probably, of seismometers, long set up in Italy and southern Europe. A pendulum, free to move in any direction, carries below the bob a stile partly immersed in a stratum of dry fine sand spread to uniform thickness over the concave surface of a circular dish placed beneath, marked to the cardinal points, whose centre is beneath the point of suspension of the pendulum when at rest, and whose concavity is that of a spherical segment of a radius equal to the length of the pendulum and stile, plus rather more than the depth of the stratum of sand. It was supposed that the stile would mark a right line when seen in a plane vertical to the sand-bed, and in the direction of the shock.

6 (*b*). The inverted pendulum, held vertical when at rest by its forming part of a spring at the base (like the watchmakers' noddy), armed with a chalk tracer or pencil above the bob, marking a line or lines upon the concave lower surface of a dish in form like that of the preceding. This was understood to be one of the instruments adopted by the observers of the repeated shocks of Comrie, &c., and the invention, in its improved form, of Prof. J. Forbes. (Phil. Trans. Edin. vol. xv. part 1; Trans. Brit. Ass. 1841-42.)

7 (*b*). The inverted spring and ratchet pendulum seismometer, proposed in 1854 by Robert F. Budge, Esq. of Valparaiso, in a letter (12th March 1854) to Mr. Patterson of Belfast, and obligingly forwarded by him to the author. Four cylindrical or square rods of spring steel, each carrying a spherical bob (an iron shot) at top, are fixed vertically. Each is provided with a ratchet, finely cut upon the rod, and a pall, the planes of motion of the four palls passing through the cardinal points, so that each spring pendulum is free to make *one semioscillation* only in its own direction, or that of its ratchet and pall, and be arrested there by the latter until its position of displacement be observed and it be released. Thus, in the figure (2), *p* W is the spring pendulum (which, it may be remarked, would be better a flat ribbon of spring steel,

the broad dimension being transverse to the arc of vibration, than either round or square as proposed), W the bob, *r* the ratchet and pall. If we suppose this to be in the N. and S. vertical plane, a shock from the S. may bring the pendulum into the position *p m*, when the pall will fall into that *r n*, and detain the instrument in its new position until the angle *n p* W can be observed.

Fig. 2.



The main object proposed by the author of this modification of the inverted pendulum was, that the observable movement of the instrument should be as nearly as possible that of the horizontal component of shock, without being perplexed with indications due to subsequent abnormal motions of the instrument.

8 (*b*). The pendulum seismometer of Santi. Two pendula suspended close to the faces of two walls, ranging in vertical planes traversing through the cardinal points, are free to oscillate in those planes only. Each is provided with a chalk tracer, which marks the arc of oscillation N. and S. or E. and W., or *vice versâ* as to either, upon the prepared face of the wall. This has been long in use in Italy. The length of the horizontal chord of the arc traced is assumed to be equal to the horizontal component of shock in the direction marked, and intermediate movements are to be obtained from comparison of the lengths of both cardinal chords by the known laws of compounded motions.

9 (*b*). A vertical inverted spring pendulum, formed of an elastic rod (wood or cane), with bobs of iron shot, is fixed within a hoop, with certain extemporaneous means of marking its oscillations in any plane, or more than one, for horizontal component. Such pendula, fixed horizontally in a wall, or in two N. and S. and E. and W. walls, may be used for vertical element, or a shot hung from a spiral spring of wire (Mallet, Admiralty Manual, sect. vii. p. 217, 218.); these were intended for extemporaneous use. The spiral spring arrangement has had several different proposers, some anterior to the above.

Such are the principal instruments of the first class, used or proposed, in addition to which may be noticed the balanced circular dish, or wheel-formed seismometer, suggested, I believe, by Professor J. Forbes and Col. James, R.E.,—a disk of cast-iron or other metal with a heavy rim, upon a central point of suspension slightly above the centre of gravity, and provided with a central tracing-stile, either above or below. The sensibility and power of horizontal recovery or stability of this instrument are nearly identical with those of the common balance. It is liable to all the objections that apply to pendula, whose properties in oscillation it still partakes of; and it is difficult to see any one special advantage offered by it.

Of the second class, or self-registering seismometers, the number is much more limited.

1 (*a*). The first completely self-registering seismometer proposed, the author believes to have been that invented by himself, an account of which

was read to the Royal Irish Academy in June 1846 (Trans. R. I. A., xxi. p. 107). It consists essentially of five fluid pendula,—glass tubes, partially filled with mercury, four for horizontal, and one for vertical elements of the shock. The displacement of the mercurial columns breaks contact, in an otherwise closed galvanic circuit, which, acting upon some simple contrivances, cause a pencil to trace a line upon ruled paper, whose length is proportionate to the time that contact remains broken, or to the amplitude and altitude of the earth-wave. The ruled paper, placed upon a cylinder, is maintained in motion by a clock; the position of the commencement of the pencil line traced on the moving paper, therefore, gives the moment in time, of the arrival of the wave, or initial instant of shock. The displacement of the mercurial columns is dependent upon inertia, and on the relative mass of mercury in the adjacent limbs of each bent tube.

2 (*a*). Professor Palmieri, of Naples, has, some time since, constructed an instrument, in point of general principle, very similar to the preceding, and which has been at work, as he informs me, with satisfactory results, at the Royal Meteorological Observatory upon Vesuvius, and for a considerable period. His instrument consists of two distinct systems, one for vertical, the other for horizontal, or rather undulatory movements. The former consists of a clock, constantly going, and registering *date* and *time*. A galvanic circuit, which includes an electro-magnet, remains always *unclosed*, except at the instant of the arrival of a vertical movement of the whole instrument, when one pole of copper or platinum wire, held suspended from a heavy bob at the lower end of a spiral spring—as in 9 (*b*), last sentence—close over the surface of a mercurial cup (the other pole), drops by inertia, and making good the contact, establishes the electro-magnet's action, and by it stops the clock and rings a bell. The *range* of vertical movement is, I believe, deduced from the direct motion of this contact-maker.

The system for horizontal (?) or undulatory movements consists of a similar clock and galvanic arrangement, and of four U-shaped glass tubes, open at both ends, and containing equal vertical columns of mercury, The vertical planes of two of these U-tubes are N. and S. and E. and W.; those of the other two in intermediate rhumbs. Close *above*, but not in contact with, the mercurial surface in one limb of each tube, is held suspended a platinum pole, the mercury itself being the other pole of the open circuit. Upon the surface of the mercury in the opposite limb a small float rests, connected by a silk cord over a pulley in a vertical plane, with a little counterpoise, slightly heavier than the float. If, now, such a movement be given to any one or more of these U-tubes as shall *kant it over or throw it out of plumb*, and so alter the relative levels of the opposite surfaces of mercury in the two limbs of the tube, the U-tube that shall incline *towards* the limb that contains the platinum galvanic pole will then make contact, and at the moment of doing so will stop the clock and ring a bell as before.

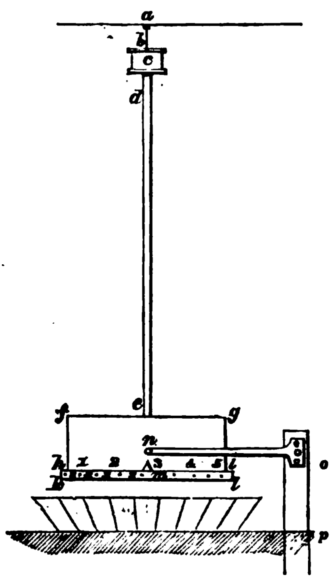
The amount of displacement as to level of the two surfaces of mercury in the opposite limbs will be made observable by the distance to which the small float shall be found elevated above the surface of the mercury in the opposite limb. A description of this instrument has been given, but without a figure, in De la Rive's

'Treatise on Electricity and its Applications,' English edition, vol. iii. p. 508*.

3 (*b*). The last self-registering instrument to be noticed is that of Herr Kreil of Vienna, of which an account appeared in 1855. This ingenious and simple instrument can hardly be made intelligible more briefly than in the author's own words, which I translate (with the addition of a word or two) from the 'Sitzungsberichte der Kais. Akad. d. Wissensch.' Band. xv. p. 111, Heft for March 1855:—

"A good seismometer is a desideratum still to be devoutly wished for. It should not only show the commencement of the stronger, but also of the weaker shocks, as well as their duration, direction, and strength,—a task which is too great for a self-registering apparatus. Therefore every idea towards the improvement of such instruments must be welcome; and on this account I venture to bring forward the following design (fig. 3). Let *de* be a rod of wood or metal suspended at *a*, which at *d* is fastened to the elastic spring *c*, like the pendulum of a clock, and therefore can swing in the plane of this spring in a vertical direction. Let *a b* be a second spring upon the first vertical one, which permits the bar of the pendulum, *d e*, to swing in the plane of the spring *c*, i.e. at right angles to the former vertical plane. The bar *d e* and the weight fastened to it can therefore swing in every direction, without its being permitted to turn on its own axis of vertical length, and as if there were but a thread or thin wire at *b*. The cylinder *f g h i* contains clockwork, which obliges it to turn round upon the bar of the pendulum (as its perpendicular axis fixed with reference to rotation) once in 24 hours. It is covered with paper or other material, which can be marked on without great pressure. It contains on the lower edge the numbers of the hours, which can move behind an index *m*, fastened to the plate *k l*, which is fixed to the axis of the pendulum. Upon a neighbouring pin, *o p*, is an elastic and thin arm of brass, *o n*, which carries a pencil at *n*, which, by means of a screw (spring?), can be pressed against the cylinder and removed from it. It is in firm contact with this, and marks upon it an uninterrupted line so long as the pendulum remains at rest; if, however, this begins to swing, in consequence of the whole system being shaken, this line will be broken, and strokes produced which will have a horizontal direction if the pendulum swings in the plane of *n o*, but will be perpendicular and crossways if swinging in the plane perpendicular to *n o*. The force and length of

Fig. 3.



* Since this report was commenced, I have myself had the advantage of seeing this instrument, and conversing with its distinguished inventor, as to its principles and construction. Prof. Palmieri informed me that it had been arrested by the celebrated shock of 16th December 1857, and had given indications that he deemed satisfactory. [R. M., May 1858.]

this stroke will give an approximation to the strength of the shocks. The middle of the stroke, or, if they are vertical, the end of the uninterrupted line, gives the time of the commencement of the shock. The strength and direction of the shocks may also be approximated if the (as respects rotation) fixed plate *h i k l* have an annular recess, filled with quicksilver until its surface reaches the holes *s s s*, made in the cylindrical sides. At the first motion of the pendulum, the quicksilver will be shed out through these holes into a dish divided into the same number of compartments as there are holes, like those already in use in many existing instruments of this kind (Cacciatores)".

Such are the chief seismometers hitherto proposed. They all involve in some form the principle either of the solid or of the fluid pendulum, the latter term being applied to the oscillations of liquids in tubes or other such vessels; and have disadvantages, both theoretic and practical or constructive, which render their indications inaccurate.

Every pendulum seismometer has a time of oscillation due to its length, which in the case of the solid pendulum is

$$T=\pi\sqrt{\frac{l}{g}},$$

and in the case of the oscillating liquid

$$T=\pi\sqrt{\frac{0\cdot5l}{g}},—$$

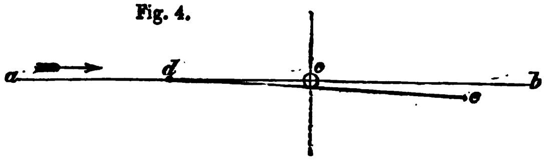
l being the length of the pendulum and of the oscillating column of liquid respectively; but if P = the period of the earth-wave or shock, then whenever $T=P$, or $n \times P$, or $\frac{P}{n}$, the indication of the instrument will be in excess of the horizontal component of the wave's motion; when, on the contrary, T represents no function of P, it may be much less than it.

The amount of error depends also upon the velocity of movement of the horizontal component of the wave. If this be considerable, the solid pendulum, whether hanging or inverted, acted on by gravity or elasticity, is at the first moment left behind; as the rod becomes more oblique, the pendulum is *dragged* along, and acquires a velocity (in a direction which approaches to horizontal) greater than that due to the arc through which the pendulum has fallen in the time. At the end of the wave's forward movement, then, the pendulum is thrown forward too far; and at the end of the return movement of the wave, it moves beyond the range of the latter, by a small arc due to its proper motion. This objection applies, though with less cogency, to the fluid pendula, and in their case to both the vertical and horizontal components of the wave.

These discrepancies of indication will vary whenever the velocity and dimensions of the earth-wave become altered; and as, for the same instrument, T varies with $\sin^2 \lambda$ (λ being the latitude), it is obvious that even two perfectly similar instruments at stations north and south of each other, will not give strictly comparable results for the same earth-wave.

These are but examples of one or two points of theoretic difficulty, to which others might be added, and which affect these instruments principally as indicators of the dimensions of the earth-wave. Some of these theoretic disturbances may be eliminated by calculation from the results; but there are also some apparently insuperable difficulties, of a practical or constructive nature, which affect all solid pendula as reliable indicators even of the direction of surface-transit (horizontal component) of the earth-wave. However finely suspended the pendulum—if acted on by gravity only, or, however constructed if by elasticity or by elasticity and gravity, it is found impracticable to produce an instrument that shall make even the second half of its very first complete vibration strictly in the plane of the original disturbance, *i. e.* in that of the wave's transit. If, for example, any one of the

Fig. 4.



instruments 5 (*b*), 6 (*b*), or 7 (*b*), be caused to make a semivibration by a movement of the nature of one horizontal jerk, and strictly in one vertical plane *a b* (fig. 4), the trace made will in most instances be found thus; *c d*, the first semivibration, is made sensibly in the plane of movement, but the returning complete vibration *d e*, is found diverging from it through a sensible angle *c d e*. If the vibration of the instrument be suffered to continue, its trace rapidly becomes an extremely elongated ellipse, whose excentricity constantly diminishes, as well as the actual dimensions of both its axes, until the instrument comes to rest, after tracing thus a mass of elliptic spirals, from which nothing certain can be gathered as to direction in some instances—in which, at best, it is only possible to arrive at a probable direction of originating impulse, by drawing a mean major axis through all these closed curves.

Constructively, this evil arises not only from the nature of the suspension, if a pendulum of gravity, or, if one of elasticity, from the form, material, &c. of the suspending or supporting spring; but also, in both sorts, from the fact that it is practically impossible that the point of suspension (or, in the spring, its centre of resistance), the centre of oscillation, and the resultant of the various opposing forces of the stile or tracing-point, shall lie in one vertical plane, and that that plane shall always coincide with that of the wave's movement; and hence lateral divergence of the pendulum and elliptic spiral oscillation. But it is also partly due to the nature of the earth-wave motion itself, which is never a purely normal one, but always more or less disturbed by small transversals; so that the initial movement impressed upon the pendulum is really not exactly that of the wave's transit. Before entering further, however, upon the subject of the actual perturbations of the superficial earth-wave, as now known, and their effects in relation to seismometers, some remarks may be advisable as to the special objections which I have either observed or experimentally ascertained in respect to each particular arrangement of the seismometers already described.

1 (*a*). The Cacciatore mercurial dish.—If the earth-wave emerge with a considerable angle from the horizon, and large velocity, the mercury first surges up at the side of the dish towards which the earth-wave is in transit, and in the direction opposite to its motion; it then, after spilling out some of the mercury, commences its return oscillation, moving in the same direction as the earth-wave, and spills out another portion at the opposite side of the dish. The sum of the weights so spilled out, taken at either side of a diameter transverse to the earth-wave's vertical plane of transit, will vary with every change in the angle of emergence, or in the velocity or in the dimensions

of the earth-wave. Small transversal vibrations, arriving almost along with the earth-wave, as well as the effects of the form of the dish, and of its delivering-spouts or adjutages, disturb the initial simple surge of the mercury across the diameter of the dish, and produce reflected and other secondary surge movements of the mercury, which traverse round the circumference of the dish, and spill out more mercury in irregular gulps. The final result is, that no reliance whatever can be placed upon its final indication, as to the plane of the earth-wave transit having passed through the centre of gravity of that semicircle of cups which are found to contain the most mercury. The result is not materially different if the line of transit of the earth-wave be perfectly horizontal. This instrument gives no information whatever beyond a most uncertain approximation to the direction of the horizontal component of the earth-wave transit.

2 (*a*). The same objections generally apply to this form of instrument, and one in addition, viz. that a viscid liquid like molasses must always give indications short of the truth as to excursion in the dish due to any given shock, and the more so as it is more tenacious and approaches nearer to a solid; and as we have no correct means of measuring viscidity, even assuming it constant for the same liquid, nor any certainty that the specific gravity of such liquids remains constant (it is certain *molasses* will not remain of the same density in any climate for any considerable length of time), so observations made through their means at different times and places can never be comparable.

3 (*a*). The same objections that apply to 1 (*a*) apply to the tub of coloured water, but in a mitigated degree, the diameter being large, the volume and depth of the liquid great, and the cylindrical sides of the tub free from any apertures or inequalities. The initial surge gives a much more distinct indication of direction than in either of the preceding instruments; and it does not very frequently happen that a diameter may not be found approximating, with tolerable certainty, to the plane of earth-wave transit. But in cases where the normal wave is preceded or accompanied by very appreciable transversals, those *violent tremors* that are now known as the frequent accompaniments of the actual shock—the water-tub seismometer will give no indication, or an uncertain one, unless watched and remarked as to transit-direction at the instant of the occurrence of the shock.

4 (*a*). Tubes partially filled with mercury give almost unobjectionable indications as to *direction* of transit. Their evils are too great delicacy or sensitiveness, for the observation of that class of earthquakes of mean power, which are the most important to be studied, and by which they are completely deranged occasionally, while they are continually being disturbed in such a seismic region by small tremulous movements that are unimportant to notice. As respects their indications of velocity and dimensions of the wave, they are liable to the objections already noticed as applicable to all pendula.

5 (*b*) and 6 (*b*). The main disadvantages of these constructions, viz. the suspended and the inverted solid pendulum have been already pointed out; it may be added here, however, that with the inverted pendulum of Forbes, the supporting spring is more or less crippled down, by a sharp vertically (or nearly vertically) emergent shock, which gives a lateral movement (greater or less) to the pendulum, as though

from a horizontal originating motion, so that the instrument gives in such cases an absolutely false indication.

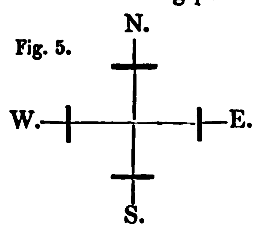
7 (*b*). Mr. Budge's inverted spring pendulum, restrained to a single semi-oscillation in one plane, offers some decisive advantages over any other form hitherto proposed of the pendulum seismometer. The whole length of the pendulum is elastic; and the rod being light, the whole weight by whose inertia it is bent may be considered as in the ball or bob. If Σ be the moment of resilience of the rod, and the deflection be not very great, the angle $w p n=\theta$, then—

$$\Sigma(L \tan \theta-b)=\frac{F L^3}{3},$$

L being the length, and b the horizontal ordinate of deflection of the pendulum. It is plain that although, like every other elastic rod, this will have a time of vibration of its own, and be therefore liable to part of the theoretic objections made to the simple pendulum on the same account, this form of pendulum will be "brought up" much more nearly within the true limits of the earth-wave amplitude in its horizontal component.

Perhaps the ratchet and pall may not be the best mode, practically, of arresting its movement at the end of its first semioscillation, with sufficient delicacy, and other methods are obvious that may be applicable; but if the elastic rod be a flat plate of sufficient breadth in relation to its thickness, and each rod or pendulum (of the four) be so placed, with reference to the cardinal points, that its broadest dimension shall be transverse to its normal plane of flexure, it is then obvious that practically we may neglect any flexion of the rod *edgeways*, the four rods in section being posited thus (fig. 5)—

Fig. 5.



and that thus we obtain a flexure, for each pendulum, practically limited to its own vertical plane of oscillation, and so can obtain, for any intermediate line of wave-transit between the cardinal points a good approximate resultant direction from the two adjacent component deflexions. Perhaps a flat ribbon-like rod of tempered steel, whose section should be a rectangle, with sides having the proportion of about 30 : 1, would be better than an elastic wooden lath; and in either case, it is probable that a tape or silk ribbon, fastened at the side r, and passing with friction through a small horizontal slot in the elastic rod, so as to be stretched by its deflexion and pulled through, would be the best and simplest mode of registering the deflexion, or the angle θ.

While this appears to me the best of the solid-pendulum arrangements, I do not wish to be understood as recommending any one of the class.

8 (*b*). Santi's arrangement is of course subject to the objections made to all pendula. It possesses some advantage in separation of the results in

different azimuths, and therein in clearness of indication; but it also has special disadvantages of its own. If, for example, the line of earth-wave transit be from S. to N., and the E. and W. pendulum be set up at the S. side of its own wall, it will tend to be thrown off or out from the wall by the shock; if placed on the N. side of its own wall, its friction will be increased on its suspensions, and tracing-point, by its being thrown in or pressed against the wall; and if the line of earth-wave transit be, say N.W. and S.E., both pendula will be either thrown out from or pressed in against their respective walls, according to which side of the N. and S. walls they be fixed at. This source of variable inaccuracy might perhaps be eliminated by a double set of pendula, viz. one at each of the opposite sides of the N. and S. and of the E. and W. walls, which would thus be oppositely affected (in excess and in defect) by this source of error.

9 (*b*). What has been already stated, with reference to errors common to all pendula, and the remarks made under 7 (*b*) as to the superiority of elastic over simple pendula, render it needless to enlarge on those which were only proposed as extemporaneous instruments, and for which they will be found convenient and useful, and not more inaccurate than much more elaborate ones.

Referring now to the second class, or self-regulating instruments,—the disadvantage of the one

2 (*a*), proposed by the author is of the same character as that of 4 (*a*) of the first class, viz. too delicate a sensitiveness to small tremulous shocks, which derange the composure of the instrument, without its giving decisive indications. The galvanic recording part of the apparatus was all that could be desired, and is of course applicable to other forms of instrument as respects the displacement portions. Indeed, apparatus identical in all its main characteristics has been since brought into successful and constant use by Professor Airy, Astronomer Royal, for the registration of astronomical and other kindred observations, and also by several experimenters abroad. An account of many such arrangements will be found in De la Rive's 'Treatise on Electricity.'

2 (*a*). The same remark, I think, may apply to Professor Palmieri's seismometer, with this addition: the movement of the mercury, equal columns of which are contained in the opposite legs of each U-shaped tube, depends in his instrument *wholly* upon the U-tube being *canted over* more or less in its own plane, so as to throw the legs of the tube out of plumb. This, Professor Palmieri (if I do not misunderstand him) considers an inevitable consequence of the transit of the earth-wave at the instrument, conceiving the earth's surface to suffer, in every case, such a sensible heaving undulation, as to rock the instrument upon it, like a ship upon a heavy ground-swell. I must confess to entertaining great doubts that, in the great majority of earthquakes, any such sensible undulation (enough, at least, to produce a sensible throwing out of plumb of the U-tubes) can occur, although I have no reason to doubt that, from its delicate sensitiveness, contact will be broken, and the instrument act in so far, by some of the violent jars or jerks that it may receive. This peculiarity constitutes, in fact, the essential difference in arrangement between the author's seismometer and Prof. Palmieri's. In the former the

mass of the mercury is in unequal columns in each tube, so that its displacement is dependent solely on inertia; it therefore sympathizes with the movement of the earth-wave, emergent in whatever way; in the latter, the correctness of indication of the instrument depends not at all on the inertia of the mercury, but simply upon the alteration of relative surface-level in the opposite legs of the U-tubes, when the latter are thrown more or less out of plumb by the supposed undulation of the earth's surface at the transit of the shock.

3 (*b*). Kreil's ingenious instrument is not devoid of some serious objections. It partakes of those common to all pendula; and these will be further perplexed when the annular dish *h i k l* is filled with mercury, which will form a second (fluid) attached pendulum with a time of oscillation of its own, and differing largely from that of the pendulum which suspends it. Very little value, however, can be attached to the indications to be afforded by the very small amount of mercury that can be caused to spill out, owing to the very small arc of oscillation that the whole instrument can be afforded to make by construction. The most serious objection, however, lies in the method of flexible suspension adopted for the whole pendulous part of the instrument, viz., by two *short* thin plates or ribbons of tempered steel, whose respective vertical planes are at right angles to each other, the object being to *allow of oscillation* in any direction, but *prevent rotation* upon the vertical axis. Whenever a somewhat energetic disturbance shall be given to a pendulum so suspended—so as to cause oscillation in a vertical plane, diagonal to the crossing planes of the two suspending ribbons, *torsion* of each of these arises, and violent twisting movements (by jerks) of the pendulum itself result, producing sudden, jerking, rotatory oscillations of the bob (the cylinder containing the clockwork, &c.) round the axis of the pendulum. These must of course interfere with and derange any true results as indicated by the tracing-pencil, which must also record all such accidental moments, and probably derange the rate of the clock.

There does not appear, however, to be any insuperable difficulty in devising another mode of suspension for the instrument, that might at least remove this defect.

Such are some of the main objections to the seismometric instruments themselves, hitherto proposed. It remains to consider the difficulties introduced by the nature of the movements we require to observe and record with them, as they actually take place in nature. What we want to find is the true direction of emergence of the normal earth-wave, with its dimensions and velocity, at a given point upon the earth's surface. This, were the earth a perfectly homogeneous elastic solid, though much easier, would still be attended with grave difficulties; one of these, which must ever remain *instrumentally* insuperable, consists in the fact that the emergent wave on leaving the free outlying stratum of the earth's surface, differs both in dimensions and in velocity from the same wave in the previous parts of its deep transit. Future and more perfect knowledge of the laws of imperfectly elastic bodies in wave-transmission will, it may be expected, enable us to calculate the latter from the observed final part of the transit.

Far, however, from being homogeneous, every portion of our earth's crust that we are acquainted with consists of various "couches," or masses of materials, differing in elasticity, density, and degree of discontinuity, in the character, directions, and openness or closeness of the discontinuant fissures, in wetness or dryness, in temperature, and in many other ways. Stratification and lamination, with their transverse master-joints, affect the elasticity of whole mountain-ranges and profound masses of the land, and cause it to differ in different directions.

The mass beneath our feet is very often not even approximately solid. Vast beds and cavernous recesses occur, empty, or filled more or less with water, sometimes with lava, ignited rock, and steam at enormous temperature and tension; and, for anything we as yet *know*, seismometry may require to deal with depths and masses where the solid has passed, with exalted temperature, into the imperfectly liquid state.

Again, the *surface* of our earth is everywhere more or less uneven, and, viewed over large areas, such as earthquake-transit is concerned with, is ribbed with rigid mountain-chains, often intersecting or abutting on each other, channeled by valleys, river-courses, deep estuaries, and bays, excavated into basin-shaped hollows often long and narrow, sometimes filled with unconformable rock or with loose and incoherent detrital material, and intersected to unknown depths by dykes, veins, and faults. The result of these differences and disturbances of internal structure and superficial features is to produce perturbations in the surface emergence of the earth wave, often of the most amazing and perplexing character; and it is not until the nature and extent of these have been realized to the mind, that we shall be enabled to choose the best form of seismometric observation, to determine upon the only proper sites for the establishment of instruments, and to see within what limits our first researches must be confined.

Let us notice, then, a few examples of striking surface-perturbation, of direction, of the great earth-wave, already on record.

Savi ('Relazione di Fenomeni presentati dai Terremoti di Toscana, dell' Agosto 1846,' p. 32–44) and Pilla ('Istoria del Tremuoto che ha devastato paesi della Costa Toscana il dì 14 Agosto, 1846,' p. 48–54) have both recorded examples of horizontal apparent movement of the earth-wave in directions orthogonal or even actually opposite to each other, and at points within very limited distances from each other, while, on the whole, there was no doubt of a ruling general direction of horizontal movement over the whole region. I can merely refer to their relations, as scarcely admitting of condensation intelligibly.

M. Perrey, in his 'Memoir on the Earthquakes of France, Belgium, and Holland' (Mém. Cour. de l'Acad. Roy. de Brux. tom. xviii.), under date of 5th July, 1841, has recorded a still more remarkable instance of surface-perturbation, which the small map (Plate XII.) of the northern and part of the central region of France, with outlines of the departmental divisions, illustrates. Those departments in which this shock was felt are marked by numerals referring to the following table. The directions of the horizontal component of the shock, as observed at the several places named, are shown on the map by a short thick arrow. A few other places where the shock was felt, but direction not observed, are marked by a large dot, and the name referred to by a letter. A few large towns, and the general range of the hilly country (running mainly in a N.W. and S.E. direction) between the two great seats of disturbance, are marked in mainly as general guides of position to the eye. This earthquake was sufficiently powerful to disturb furniture, move objects visibly, and affect clocks, &c., and was variously reported to have lasted in different places from two or three, to ninety seconds of time.

Number on Map.	Department.	Locality.	Direction of Horizontal Component.
1.	Seine	City of Paris	N.E. to S.W.; three shocks.
		Sèvres	W. to E.; three shocks.
		Chevreuse	N.E. to S.W.
		Longjumeau, *m*.	Direction not given.
2.	Seine et Oise	Rambouillet	W. to E.
		Grignon	N.E. to S.W.
		Orsay	S. to N.; seven shocks.
		Meulan	N. to S.; three shocks.
3.	Loiret	Nogent	N. to S.
4.	Loire et Cher	Quincay	W. to E.
5.	Indre et Loire	Caumacre	N. to S.
6.	Indre	Langè	S. to N.
		Le Blanc, *n*	More than one shock; direction not given.
7.	Cher	Bourges	Vertical (soulèvement); two shocks.
8.	Eure et Loire	Chartres, *p*.	One shock; direction not given.
9.	Seine et Marne	Donnemaire	S. to N.; three shocks.
10.	Eure	....	No record of the shock having been felt in either of these departments.
11.	Oise		
12.	Côte-d'Or	Bligny-sur-Ouche.	Three shocks; direction not given; very severe.

Here, then, we have two very limited but separated earthquake districts—one around Paris, the other more widely spread around Tours—and a third to the S.W., stretching into Côte d'Or, in which we have the observed or horizontal direction of shocks from N. to S., from S. to N., from W. to E., and from N.E. to S.W., and in one place said to be vertical. In the Paris district the extreme distance apart of the places of observation does not exceed 30 English miles, the average being under 15 English miles.

In the Tours district the extremes are under 70 English miles apart, and the average distance under 30 miles. The central part of one region is not more than 150 miles from that of the other; and neither district is more than about 70 miles distant from the axial line of the chain of hills that separates them, and in the prolongation of which to the S.W. the third district is widely spread, taking the general line of axial direction.

Making every abatement that imperfect observation can justify, there remains abundant proof, in this example, that even in places within view of each other as to distance, but situated over heterogeneous formations, and in a country of broken and irregular surface, the superficial direction of shock may present anomalies at first sight apparently admitting of no analysis, and in any case incapable of giving any direct information as to prevailing direction, or position of focus, by mere seismometric observations.

The third and last example we shall take from India, as one not devoid of a larger interest also. In the map (Plate XIV.) a very rude outline is given of the geological formations of India, in a merely seismic relation however, *i.e.* with reference to relative hardness, density, and elasticity of the rocky masses,—thus distinguishing them only into the six great divisions of crystalline or granitoid, old stratiform, secondary (from carboniferous to cretaceous), tertiaries, alluvial plains, and some igneous porphyries, diorites, &c. In the colouring of this I have to acknowledge the kind assistance afforded me by Professor Phillips. This map has been fully described in "Second Report on the Facts, &c." (Brit. Assoc. Trans. for 1851, p. 313 *et seq.*), where it should have appeared originally, but was, at a late moment, prevented by an accident connected with its completion. I shall therefore, referring the reader to the former report, merely notice here the facts as relating to seismometry.

The great earthquake of 1819, which extended its influence right across this peninsula from Calcutta to Cutch, and during which the Ullah Bund was elevated, and the Runn of Cutch submerged—the former a low mass of sand and clay seventy miles long, about fifteen miles wide, and elevated about 10 feet; and the latter an area of subsidence of about 2000 square miles—had a great general line of horizontal propagation of shock, as shown by the heavy red line, of nearly from W. to E., a few degrees to the S.E.; yet at Calcutta it was felt from N.E. to S.W., and at many places along this immense line—situated between the Aravulla and Vindhya chains of mountains, as for example at Rampura—the great shock was felt in directions quite transverse to the principal line.

So also the general line of horizontal direction of the great earthquake of 1833, whose origin was far beneath the Himalayas to the E. and N., had a great general direction about that shown by the long red arrow line. At Katmandu, in the mountains, the shocks were more directly E. to W., and also (reflected shocks probably) from the ranges to the N., which had a direction nearly N.E. to S.W., while in the great plain of the Ganges the observed directions were various, and, without a more complete knowledge of the geology and surface-configuration of the country, perfectly unanalysable, in some places N. to S., and at others, sixty miles off, from E. to W.

While we must regard many of these observations as deserving of little stress as to accuracy, enough remains to prove that perturbations in the main directions of emergence at the surface of the normal earth-wave, due to heterogeneity of structure in depth, and to inequality of surface, principally, are of such a nature, as to render a special choice of district necessary in attempting any seismometrical researches (even with perfect instruments) which have in view the determination of the position of the focus of disturbance. This choice, according to our present knowledge, must be determined by the following conditions:—

1. The whole surface-area of observation, and to as great a depth as possible, must be uniform in geological structure.

   If of stratified rock, not greatly shattered and overthrown, but (viewed largely) level or rolling only. The harder and more dense and elastic the formations, the better, but neither intersected by long and great dykes, nor by igneous protrusions of magnitude, nor suddenly bounded by such formations.
2. The surface must not be broken up into deep gorges, and rocky ranges, and valleys. Seismometry, in a high and shattered mountainous country, can scarcely lead to any result but perplexity. If the surface be deeply alluvial all over, it is less objectionable than valley-basins, and pans of deep alluvium, with rocky ribs between them.
3. The size of the area chosen for observation must bear a relation to the force of the shocks experienced in it. *Moderate shocks are always best for observation, and, in large areas of the most uniform character of formation and surface, will give the most trustworthy indications.*
4. If several seismometers be set up in the area, they should be all placed on corresponding formations, either all on rock, or all on deep alluvium. The rock, when attainable, is always to be preferred. Three seismometers, at as many distant stations, will be generally found sufficient, if the object be chiefly to seek the focal situation and depth.

Having now cleared the way by stating the difficulties of seismometric observations, 1st, as respects the instruments themselves, 2nd, as respects their local emplacement, it remains to describe the instruments that appear to me the best calculated for the attainment of the objects we can at present propose to ourselves in seismometry, and to point out how such may best be applied; as also some indirect methods of arriving at the most important and interesting primary result, that we are entitled to expect in the first instance from such researches, namely, an approximation to the actual depth of focus within the earth, from which earthquake-impulses are propagated to the surface.

Were it possible to construct a perfect seismometer, it should record simultaneously, 1st, the movements, both horizontal and vertical, of the elastic wave itself, viz., the excursion or amplitude, the altitude, and the maximum velocity in the coordinates x, y, and z,—z being vertical; 2nd, the movements of translation of the "advancing form" or wave itself at its emergence upon the earth's surface, with the velocities in the corresponding coordinates x_2, y_2, and z_2.

These involve alone twelve equations of condition; and we *assume* that the elastic medium (the earth) through which the wave is transmitted, is homogeneous, in density and elastic modulus; and that the final wave-movements, of the free outlying stratum at the surface, obey the same laws as do those of the successive "couches" beneath.

Generally, we must assume the elasticity perfect, and that the *vis viva* of any particle in motion, Δm, is determinable from its velocity at its position of equilibrium. From the general equation of wave-motion

$$v = a \cos\left(\frac{2\pi}{\lambda}(x - at)\right),$$

we have the velocity at any point where a^2 is the intensity, λ the amplitude, a the transit-rate or velocity of propagation, x the abscissa, and t the time.

At the position of equilibrium $v=a$, and the *vis viva* of the particle Δm during the whole undulation is $\Delta m a^2$, and proportionate to a^2. The wave we must suppose emanating from a central point, and propagated outwards in all directions alike, in imaginary, concentric spherical "couches." The *vis viva* must remain constant during the whole propagation. The velocity of propagation a is also constant; and *the mass of the medium in wave-motion at any moment of the translation is the same*; so that, if r=the radius of any such spherical "couche," the work done in it by the wave is proportionate to $r^2 \times a^2$, and constant for the whole transit, a^2 being $\propto a\frac{1}{r^2}$. As, therefore, the mass in simultaneous undulation is constant, the thickness of each imaginary successive "couche" must decrease as r^2; and so the displacing power of the wave diminishes also as r^2, and the work done by the wave within any such "couche" of determinate thickness$=\Sigma\frac{1}{2}\Delta m a^2$,—or M, being the mass in simultaneous undulation, $=\frac{1}{2}\mathrm{M}a^2$.

The wave at its origination, starts in any radius, with one normal and two transversal vibrations, the separate determination of which would require a corresponding increase in the number of equations for x, y, and z; and in the recorded facts by the instrument. It is obvious, then, even with the utmost simplifications we can assume as to the molecular condition of the medium (the earth), that practically we must be content with a seismometer that shall record only some of the more important conditions of the earth-wave, and in such a manner as shall enable us, indirectly, to arrive at others. And in considering the relative importance of the several elements, the maximum velocity of the wave at its point of emergence upon the surface, with the directions in x, y, and z, or the horizontal components (x and y) of the direction of motion and the vertical component z, will be found the most valuable.

These are determinable by one instrument only. By two or more such, at separate and moderately distant places, the velocity of propagation or transit-rate α may be found; and by combining the results obtained by both, in calculation, each may be made to check and control the other, and for a given seismic region (apart from serious perturbations of internal formation) we can obtain the point upon the surface, vertically above the origin of the wave, and approximate to the depth of the origin itself, or of the focus of disturbance, below the earth's surface.

One or other, of two distinct seismometric arrangements, may be adopted, both dependent upon similar principles,—the second being of a simpler and less expensive character, but not susceptible (as a *single* instrument) of indications as accurate as the first, yet, as respects applicability to determinations of *time* (as one of several, set up in a given seismic area), quite as exact.

I proceed to describe the construction of both, their principles and action.

The first instrument is exhibited in Pl. XV. figs. 1, 2 & 3. Fig. 1 is a lateral geometric elevation of the instrument, whose length is placed in the direction N. and S., as seen in plan in fig. 2,—a precisely similar instrument being placed at right angles of azimuth to it, or with its length E. and W. The same letters of reference apply to similar parts in all the figures. Fig. 2 represents both the N. and S. and E. and W. instruments as placed in position, *w w* being part of the external wooden shell or wall of the seismic observatory, which may best be always of wood, or such material, and circular in form.

In figs. 1 and 2, *a a* is a cast-iron tabular bar, whose upper surface is horizontal, and whose long parallel edges are either N. and S. or E. and W. It is attached to a rigid cylindrical vertical bar of wrought iron, *b b*, which passes freely, but without shake, through bored holes in the top and bottom collars of the heavy cast-iron frame *c c*, which is firmly bolted by its bottom flanch to the heavy stone floor of the observatory; or, if the latter can be so placed, to the natural solid rock when levelled to form its floor. Beneath the frame *c c* is a pit, *p p*, for convenience of access to the bottom of the instrument. Upon the vertical bar *b*, a collar is fixed of wrought iron, *k*, between which and the lower bored collar of the frame *c c*, a spiral spring, *e*, is placed, having its axis coincident with that of the bar *b*.

This spring sustains, when at rest, the weight of the bar and table *a a*, and of all resting upon it, and is so adjusted as to resistance, that such forces in the vertical direction, as it may be expected the instrument will be exposed to at any time, shall not be able to compress the spring to such an extent, as to bring the lower surface of the table *a a*, into contact with the top part of the frame *c c*. A vertical "feather," let into the bar *b*, prevents it, or its superior attachments, from altering their position with reference to the frame *c c*, by turning round the vertical axis of the bar *b* in its collar-bearings.

A small sliding index, not shown in the figure, also moves in a longitudinal groove at the opposite side of the bar *b*, and, being placed in contact with the top of the frame *c c*, when the whole is at rest, indicates the extent of any vertical depression of the bar *b*, and of its load, by compression of the spring *e*. A buffer collar of vulcanized india-rubber is placed at *l*, above the iron collar *k*, as a precaution against a jar, in case of the sudden removal of part of the load on *a a* by any accident.

Upon the upper side and centre of the length, of the tabular bar *a a*, is cast a hollow quadrilateral prism, *g*, which will be called "*the block*," provided with four "lugs" to receive the pivot-screws *n*, *n*, *n*, *n*. The table *a a*, supports two similar cast-iron inclined planes *i*, *i*, having for their entire length the trough-shaped section as shown in fig. 3. These planes are fixed to the table *a a*, by the pivot-screws *n*, *n*, and by the adjusting-screws *m*, *m* beneath, so that by means of the latter, the inclination of either plane may be altered or fixed, being otherwise free to rotate in a vertical plane, within certain limits, round the pivot-screws *n*, *n*, so as to alter the angles of inclination.

Upon each of these inclined planes, is placed a large heavy ball, formed of a hollow sphere of hard gun-metal, of about 0·3 of an inch in thickness, truly spherical and polished outside, and filled up solid with lead. These balls are adjusted in diameter, to the breadth and form of the inclined planes (as in fig. 3), so as freely to roll along, with but two points of contact.

When the planes *i*, *i* are adjusted at equal inclinations, the balls B, B_2 rest at their lowest ends, and are laterally in contact with, and supported by, the hard wood stops *r*, *r*, driven (from outside inwards) through, and well-fitted in, corresponding rectangular horizontal "slots" in opposite sides of the block *g*,—the end of each wood stop being curved to fit the surface of the balls, in a horizontal great circle, and so that the plane of the stop passes through the centre of gravity of the ball. Through each wood stop there pass the $\epsilon-$ and $\epsilon+$ extremities of a galvanic conducting-circuit of thick copper wires, placed at about an inch apart, where they pass parallel to each other, through the wood stop, with their extreme ends coinciding with the surface of the stop next the ball, and being amalgamated; so that while ever the ball reposes in contact with the wood stop, the galvanic circuit remains *completed, through the ball*, between the ends of the wires, but is broken the moment the ball is removed from contact with them.

For one complete seismometer there are two such instruments as have been thus described,—one placed, as in fig. 2, in a N. and S., and the other in an E. and W. direction, as respects their length, and having thus four inclined planes and balls, each with its own distinct galvanic circuit from one common battery. A clock placed in the observatory carries round a cylinder with ruled paper, and each of four pencil markers continues to describe an unbroken line thereon so long as the balls are in contact with the blocks (or wood stops and galvanic poles); but (by an arrangement precisely similar to that described for my fluid pendulum seismometer—Trans. Roy. Irish Acad. vol. xxi. p. 107) the moment any ball ceases to be in contact with the block, and for as long as it is so, the pencil is withdrawn, and leaves a break in the otherwise continuous line traced by the rotation of the paper. No part of this clockwork registering-arrangement is shown in the Plate, as several modifications of it are practicable, and no one in particular is essential to the principle of the seismometer before us.

To illustrate the mode of action of the instrument,—returning to fig. 1, suppose it to be the N. and S. one, and adjusted so that the bar *b* is truly vertical, the parallel sides of the inclined planes *i* and *i* truly *in directum*, their angles of inclination to the horizon the same. Then if the arrow Q represent the direction of emergence of an earthquake-wave (supposed here to be in the plane of the meridian, and from S. to N.), at the first instant that the wave reaches the instrument, the bar *b*, and table *a a*, with all they carry, will commence to descend and to compress the spring *e* by their inertia, with a velocity dependent upon the vertical component of the wave, which carries up the frame *c c* vertically. Also at the first instant of arrival of the wave, the ball B_2, in virtue of its inertia, will move off from the block towards C_2; and *the instant of its departure, by breaking galvanic contact of the poles at its stop, marks that of the commencement of the shock.* But the whole instrument is carried forward by the horizontal component of the shock, and *then moves back again*; the ball B is therefore carried forward also, urged by the block at *r*, and is caused to roll up along the inclined plane a certain distance, say to C, where it comes to rest, and, reversing its motion, rolls back again by gravity, and returns to rest in contact with the block and galvanic poles of its own stop. *The ball which first moves*, which we may call the Time Ball (as indicated in time by the pencil trace on the clock-cylinder paper), will *always be that at the side from which the shock arrives.* We neglect any account of *its* subsequent motions. The other ball, which we may call the Element Ball, by its movements gives us the elements of the wave. The instrument records *the whole time* that it is out of contact with the block *g*, viz. that of its excursion up and down the inclined plane *i*. If, in place of the wave having emerged at some angle to the horizon from S. to N., it had come at the same or at any other angle of emergence between vertical and horizontal, in the reverse direction or from N. to S., then the action of the balls also would have been reversed, B becoming the Time Ball, and being *left behind*, and thus noting the moment of arrival of the wave; and B_2 being thrown up along the inclined plane *i*, giving its elements.

Again (referring to fig. 2), if the wave emerge at some azimuth between N. and S. and E. and W., suppose from the S.W., with any angle of emergence, then by the vertical component the springs of both the N.S. and E.W. instruments will be compressed (and nearly alike). The time balls B_2 of the N.S. and B_2 of the E.W. instruments will be left behind, as before, (and both at the same instant will break contact with the block); and the element balls B and B will be thrown forward upon their respective inclined planes, as before—to equal distances in the case of the exactly intermediate azimuth here supposed, but to unequal distances if this azimuth be more to the W. or to the S. The instrument records the simultaneous excursions of both balls B and B, giving the total time (as before) that each ball is out of contact with its own block or stop; and if the direction of the wave-movement be reversed as respects the instrument (suppose, from some point of N.E. towards S.W.), then the respective movements and functions of the balls will also reverse themselves, B and B being left behind, and B_2 and B_2 thrown forward, &c.

The general size and strength of the instrument must be determined with reference to the degree of violence of the earthquake-shocks to be anticipated in the seismic region it is intended for. The very greatest, and the very smallest perceptible shocks, are alike unsuited for useful measurement. The dimensions of the instrument, as shown by the scale of the plate, are such as I consider fitted to ensure its functions, under the effects of those shocks of mean intensity (such for example, as those common in the Mediterranean basin, or in those of Hungary and Austria), and with moderate vertical angles of emergence, which are those best to observe in the existing state of our knowledge.

The most important points of precaution of a constructional character to be noticed are the following:—The balls should be of lead chiefly (the surface being formed, for hardness and smoothness, of gun-metal), to reduce their proper elasticity as much as possible. The inclination of the planes *i*, *i* must be small, probably never exceeding 15°, and the length and inclination so adjusted by experiment, to the maximum time of wave-oscillation in the district of observation, that the whole time of rolling up and down of the ball shall be considerably longer in duration. Their bearing-edges must be perfectly parallel and smooth; and the length of the planes must be such, as to make it highly improbable that any ball, in its excursion under shock, can reach the upper end. A wood stop is fixed at this point to arrest the ball, should it ever chance to reach it; and beyond this a stout net (like the purse of a billiard-table) may be fixed to a separate support (from the floor), to receive the ball, if upon an extraordinary occasion thrown out of the instrument.

It is assumed that any alternate alteration of the inclination, of the inclined planes *i*, *i*, by actual *surface-undulation*, carrying the whole instrument with it at the passage of the earth-wave, may be neglected, *i.e.* that, for example, a wave passing in a direction from S. to N. will not sensibly lift up the S. end (of the N. S. instrument) first, and then the N. end, and so first increase the inclination of the plane of B_2 and reduce that of B, and then *vice versâ*; and that whatever amount of *tilting* may thus occur will so *momentarily* affect the inclined planes, and in opposite directions, as not to interfere with the proposed movements of the balls.

This assumption is justified by the fact that the value of λ, the amplitude of the earth-wave in the normal, is always great in relation to its altitude, and in the case of oblique surface-emergence its horizontal component is of still greater length; so that the angle of slope of either face of the emergent wave with the horizon, is practically imperceptible in moderate shocks; and, further, any tilting that can occur takes place in opposite directions successively, so as nearly to compensate.

The vertical spring *e* must be delicate and sensitive, at the first instant of its compression, in proportion to the movement by inertia of the large mass that it carries, and its range, proportioned to the degree of steepness of emergence to be expected in the region of observation.

The whole vertical component is absorbed by this spring, and may be measured by its compression; but it is important that it shall give way sensitively, at the first moment of shock, in order that neither of the balls shall have any tendency to rise from the inclined planes that support them, and that its resilience shall not be too lively, so as not to produce rebound upon the restoration from compression. In certain seismic regions, where great steepness of emergence may be looked for, the vertical component will probably be best met by the depression of a conical float with the apex downward, fixed to the lower end of the bar *b b*, into a cylindrical vessel of water placed beneath the instrument; but this must be matter of experiment in such regions.

Were the whole instrument rigidly fixed to the ground, the latter as well as the materials of the instrument and ball highly elastic, and the velocity of emergence of the wave, in its vertical component, very great, it is obvious that time would not be afforded to the ball B, merely to *roll* up along the plane; it would be *thrown up* obliquely from it, and, describing a short trajectory, would fall back again upon the plane a little higher up, and then repeat a still shorter trajectory, or begin to roll upwards. But the ball is very inelastic, the rate of emergence of the wave is not very great in its vertical component; and the effect of this upon the instrument is spread over a still longer time by the interposition of the spring *e*.

If t=the time of the wave in seconds, $\frac{t}{2}$ will be nearly the instant of its maximum velocity v, in feet per second; thus the condition that shall ensure the ball B *rolling only*, and not being projected, is that the vertical component of v shall be less than

$$v=32\frac{t}{2}.$$

Unless, possibly, in the case of nearly vertical emergence, and from the most solid, and elastic crystalline rock, an ample latitude, t, is secured by the vertical spring.

We will now consider the movements of the element balls B and B_1 along the planes i, i, due to the horizontal component of motion, taking the two instruments (viz. the N. S. and E. W. seismometers) together, and assuming the horizontal component in any azimuth θ.

The blocks $g\,r$ (N. S.) and $g\,r$ (E. W.) move forward horizontally, and force on the balls B and B_1 before them until the instant, $\frac{t}{2}$, when the blocks have acquired their maximum velocities, with that of the wave, v; the balls then part company from the blocks, and continue to move up along the respective inclined planes i, i, *sliding* for the first indefinitely short moment, and then, with a certain reduction of velocity due to the friction of the planes which produce the change of motion, *rolling* up along them. This initial sliding velocity will be

$$\text{For the ball B} \ldots \mathrm{V} = v \sin\theta;$$
$$\text{For the ball B}_1 \ldots \mathrm{V} = v \cos\theta.$$

As soon as the sliding is converted into rolling motion by friction, these velocities will become

$$\frac{5}{7} v \sin\theta, \text{ and } \frac{5}{7} v \cos\theta.$$

Assuming that the change takes place almost instantly after the balls have begun to move from the blocks, *i.e.* that gravity has not had time perceptibly to alter the velocity up the plane, and neglecting the small effects, due to the elastic compression of the balls and blocks themselves, and also supposing that the *loss* of velocity of the ball, by conversion of its sliding into rolling motion by friction, is less than the diminution of velocity of the block (in the same short time), in returning from its maximum velocity to rest, the balls B and B_1 will be retarded by forces—

$$\text{For B} \ldots\ldots\ldots \frac{5}{7} g \sin i,$$

$$\text{For B}_1 \ldots\ldots \frac{5}{7} g \cos i,$$

i being the common inclination of the planes.

The ball B will therefore ascend upon its plane to a vertical height

$$\frac{\left(\frac{5}{7} v \sin\theta\right)^2}{\frac{10}{7} g} = \frac{5}{14} \frac{v^2}{g} \sin\theta = \mathrm{H};$$

we have therefore

$$v \sin\theta = \sqrt{\frac{14}{5} g \mathrm{H}}.$$

So also the ball B_1 will ascend to the height

$$v \cos\theta = \sqrt{\frac{14}{5} g \mathrm{H}'};$$

therefore

$$\tan\theta = \sqrt{\frac{\mathrm{H}}{\mathrm{H}'}}$$

and $$V=\sqrt{\frac{14}{5}g\,(H-H')},$$

or, if $g=32$, $$V=\sqrt{\frac{448}{5}\,(H-H')}=\sqrt{89{\cdot}6\,(H-H')}.$$

This calculation assumes that the sliding is converted into rolling motion in an indefinitely short time, as it would in fact be, if the adhesion of the balls were large, and the inclination of the planes i small; but if the inclination of the latter be considerable, as 15° or upwards, a more exact determination is necessary.

Let, as before, the horizontal components of the velocity with which the balls begin to move, be $v \sin \theta$, and $v \cos \theta$, Z the velocity in the vertical, and the inclination of the planes i now large.

The initial velocity of ascent parallel to the planes will be,

For the ball B .... $v \sin \theta \cos i + Z \sin i$,

and For the ball B_1........ $v \cos \theta \cos i + Z \sin i$.

Let ϕ be the coefficient of frictional adhesion, of the balls to the plane; then they will ascend the planes to the heights,

$$B \ldots\ H=\frac{(v \sin \theta \cos i+Z \sin i)^2}{2g}\cdot\frac{2 \tan i+5\phi}{2 \tan i+7\phi},$$

$$B_1 \ldots\ H_1=\frac{(v \cos \theta \cos i+Z \sin i)^2}{2g}\cdot\frac{2 \tan i+5\phi}{2 \tan i+7\phi}.$$

v and θ are known if the value of Z be given; and this may be ascertained experimentally from the compression of the vertical spring; or, as suggested by my friend Dr. Harte, to whom I have been indebted for these equations, a second pair of experimental inclined planes and balls might be used, with an inclination greater than i (say $2i$), from the observed movements upon which, two more equations could be got, the four equations being then more than enough, to determine v, Z and θ.

But the nature of the instrument is to record the values of H and H_1, *in terms of the whole time* that the balls B and B are *out* of contact with the block *gr*, *i. e.* of their rolling up, and down, the inclined planes,—this time being given, by the lacune in the pencil-trace made upon the revolving cylinder of paper carried along by the clock. The time of the balls' ascending to the highest point reached on the plane will be independent of adhesion; and calling it t, we have,

$$\text{For the ball B} \ldots\ldots\ t=\frac{v \sin \theta \cos i+Z \sin i}{g \sin i};$$

$$\text{For the ball } B_1 \ldots\ldots\ t_1=\frac{v \cos \theta \cos i+Z \sin i}{g \sin i}.$$

The time of descent back to the starting-point, due to the heights H and H′, will be a little, but inappreciably, less than this.

The entire time of the double oscillation of each ball, therefore, or its movement up and down the plane, as recorded by the instrument, is,

$$\text{For B} \ldots\ T=\frac{v \sin \theta \cos i+Z \sin i}{g \sin i}\left(1+\sqrt{\frac{2 \tan i+5\phi}{2 \tan i+7\phi}}\right);$$

and $$\text{For } B_1 \ldots\ T_1=\frac{v \cos \theta \cos i+Z \sin i}{g \sin i}\left(1+\sqrt{\frac{2 \tan i+5\phi}{2 \tan i+7\phi}}\right),$$

the coefficient ϕ being always $=\tan \alpha$, the angle of sliding for the surface-material of the balls upon that of the inclined planes.

Reverting now to the time balls B_2, B^2, those which, *being left behind*, record the instant of the arrival of the shock at the instrument,—it has been stated that we have no occasion to determine their subsequent movements; it may be well, however, to clear our notions generally as to what these will be. Rotation is almost instantly communicated to these balls by adhesion with the moving planes on which they rest. The block moves off horizontally (in the direction of the wave) from the ball, which rolls thus with a retarded motion up the inclined plane in a relatively opposite direction. The block attains its maximum velocity V, and, coming to rest, reverses the direction of its own motion, and now follows back after the ball that it had left behind, which it *may* overtake, and *strike*, with a relative velocity equal to the sum of its own velocity and that of the ball, or to their difference, dependent upon the state of motion of the ball at the moment of impact. The impact calling forth elastic force from ball and block, the former will be thrown up along the inclined plane; but the extent of this movement, or whether it occur at all, will depend upon the dimensions and velocity of the wave itself (resolved into the line of movement on the inclined plane) and upon the elasticity, &c. of the ball and block. These we have no occasion to pursue further: the *actual* movements of these balls, B_2 and B^2, however, will be found recorded in time also, by their own pencil-tracers on the cylinder; but the only indication that concerns us, is the first instant of broken contact, as already explained.

A *single* seismometric observatory, such as has been now described, set up within a given region of disturbance, is capable of giving the elements, necessary for the calculation of the position of the seismic focus, but without the power of controlling the accuracy of the results, except in so far as coincident repetitions may confirm or refute them. But if *three such* seismometric observatories be set up within the region chosen, in positions that shall form the angles of a triangle with respect to each other, at moderate distances apart (from 15 to 30 miles), and these be all connected by galvanic wires, so that the whole of their records shall be made upon a single paper cylinder, moved by a single clock in one of the three observatories, we then have a further control, and an independent method of obtaining, both the horizontal component of direction, and the surface-velocity, from which, by methods yet to be stated, the depth of origin may be calculated without direct ascertainment of the vertical component in Z. The cylinder must in this case carry twelve pencil-tracers, four leading from each observatory.

This leads us to the second and somewhat simpler form of seismometer proposed by me, and shown in figs. 4, 5, 6 and 7 (of Plate XV.). In some respects, the principles of this instrument are the same as of that just described: like the former, it is a double instrument, each instrument having two moveable balls; but their action is different. Fig. 4 represents, in elevation, one of these instruments (let us suppose, that N. S.) as seen looking eastward, and the upper part of which is seen in plan in fig. 5. *s s* is the floor of the observatory within which the two similar instruments are placed. *t t* is a shallow and flat-bottomed dish or basin of some feet in diameter, and about nine inches in depth, formed by a circular wooden curb or rim secured to the floor.

In the centre of this, there stands up vertically a very stiff pillar or upright, rigidly secured into the floor, and which may be either of hard stone, hollow cast iron, or of hard wood, but best of the second. Its upper end is formed of wrought or cast iron in the form shown; and into it are secured the vertical supports of hardwood, *s*, *s*, which are placed with their parallel and vertical axes in the plane of the meridian or at right angles thereto, and are prepared, so as to support the balls B and B_2 upon their upper ends, which are *slightly* hollowed to the same curve as the surface of the balls, as seen at full size in fig. 7. The balls, when in this position, rest against and are steadied by the hollow stop over the axis of the vertical pillar, *b* in figs. 4, 5, and 6.

The balls may be common cast-iron cannon shot, chosen of good spherical form and of equal weight; and each ball is in metallic connexion at one point of its surface with a galvanic-circuit wire, of which it forms one pole, marked *e t*,—the supports *s*, *s*, and the stop *b*, being all of hard wood or other insulating material, as pottery or glass. The height of the central column should be such, that the centre of gravity of each of the two balls, when on their supports, may be some submultiple of 32 ft.$=g$ (say 8 feet $=\frac{1}{4}g$), for facility of calculation.

The shallow basin *t t* is subdivided in two semi-circular separate areas, by a wood division, *d*, equal in depth to the outer rim, this division crossing in the diameter which lies at right angles to the plane of the supports *s*, *s*,—*i. e.* being east and west for the north and south balls, and *vice versâ* in the other instrument. Each segment of the shallow basin is lined within its outer rim and bottom with sheet-lead, which is at one point of each in metallic contact with the other pole of the galvanic circuit marked E_2—.

The two segments of the dish are filled up to the level of the surrounding rim, with a bed of damp sand, pressed uniformly and "struck off" level to the rim by a straight edge, so as thus to present a uniform bed 9 inches deep, the balls B, B_2 being 6 inches in diameter and 8 feet above it. While the instruments (i. e. that N.S. and E.W.) are thus prepared, the galvanic circuit remains constantly *broken*, the poles formed by the balls being insulated from the other poles formed by the sand-beds, the lead lining, &c. Suppose now, in fig. 4, an earthquake-wave to emerge from S. to N. in the direction of the arrow; the ball B_2 is *left behind* as in the former instrument, topples off its slender support *s*, and commences to fall to the surface of the sand. The moment it strikes the sand, it makes contact with its own circuit, and as the time of its fall can be exactly calculated and is constant (neglecting the small resistance of the air), this ball (as before) marks the precise moment of the arrival of the shock at the instrument. The other ball B is urged forward by the movement of the whole instrument in the direction of the arrow, or that of the wave's emergence, being supported by *s* and *b*, until the instrument acquires its maximum velocity *v* as before. This ball is then thrown off from its support with this velocity, and, describing a small trajectory in air, falls to the bed of sand, and in its turn makes contact with its own galvanic circuit. The ball partially buries itself in the damp sand at the spot it falls upon, without change of position from any elastic effort, all such being absorbed by the "deadness" of the sand. If the shock has been in the plane of the meridian, the place where it shall land on the sand-bed will also be in that plane, say at B′.

Then the horizontal distance from the centre of its support *s* to the centre of the ball, measures the horizontal component of the velocity, this space being described by it during the time of its descent through eight feet. The difference in time (as shown upon the ruled paper by the pencil-tracers and clockwork as before) between the instant of B_2 and of B leaving their supports, is almost exactly $=\frac{t}{2}$, or half the time of the wave.

The same explanations will apply to the other, or E. and W. instrument; and if the azimuth of emergence θ be somewhere between N. S. and E.W., all four balls will be displaced, and the *obliquity of throw* of each of the balls

B (N. and S.) and B (E. and W.) from their respective cardinal and vertical planes, will indicate the actual azimuth of the horizontal component of the earthquake wave—giving this indication in two ways, each controlling the other,—viz. by direction of throw as stated, and by distance of horizontal traject, which will be proportionate to sine and cosine θ.

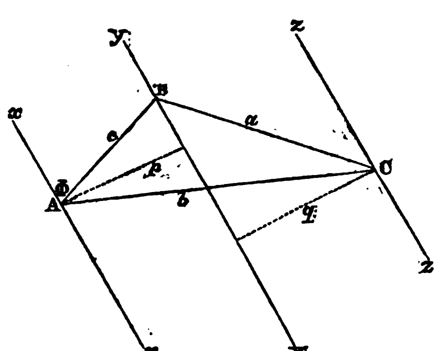
The stop *b*, it should be remarked, is hollowed at contact with each ball, so as to embrace 90° of its horizontal great circle; so that in case $\theta=45°$ from the meridional or the E. and W. planes, the balls cannot slip aside, but must be thrown in the same direction, the extreme angles of the stop then passing through the plane of motion and centre of gravity of the balls.

Figs. 5 and 6 show in plan the relative positions of the N. S. and E.W. instruments, the upper portions alone being represented, and not at the necessary distance apart.

These instruments singly, then, give us the velocity of the wave and its direction in azimuth with considerable accuracy; but their full value would only be ensured by placing three such seismometers within a given district (as already stated for the former instrument) and connecting them all by galvanic wires, so that the indications of the three shall be recorded by a single clock register. We then have the *time of arrival* of the shock at each seismometer given with perfect accuracy, from which both its horizontal velocity and azimuth may be computed; and the relative positions and distances apart of the several seismometers being known, the true direction of emergence of the wave, and the point of the surface vertically over the origin, and the depth of the focus itself may be computed. The two following methods of computing these are due to Professor Haughton, of Trinity College, Dublin, who communicated them to the Geological Section of the British Association at Dublin, on the occasion of this report being read, and from whom I have received them for publication here.

The determination of the "coseismal line"—a term first used by me at the suggestion of Sir John Herschel, to signify, the crest of the simultaneously emergent earth-wave upon the earth's surface at any moment of its progress—is the same thing as determining the direction of its motion on the surface, a horizontal tangent to the coseismal line at any point being always orthogonal to the direction of motion.

Given the Times of an Earthquake Shock at three places, to determine its Horizontal Velocity and Coseismal Line.



Let A, B, C, denote three stations at which the time of arrival of the earthquake shock is determined by the seismometers or other means, and let

a, b, c, denote the distances between them; let v denote the unknown horizontal velocity; and let Φ denote the unknown angle made by the coseismal lines x A x, y B y, with the line A B joining the first two stations; and t_1, t_2, t_3 be the times of the observed shock at A, B, C, respectively.

Letting fall the perpendiculars p and q, we find,

$$v=\frac{p}{t_2-t_1}=\frac{c\sin\Phi}{t_2-t_1} \quad . \; . \; . \; . \; . \; . \; . \quad (1)$$

$$v=\frac{q}{t_3-t_2}=\frac{a\sin(\mathrm{B}-\Phi)}{t_3-t_2} \quad . \; . \; . \; . \quad (2)$$

Equating these two values of v, we find

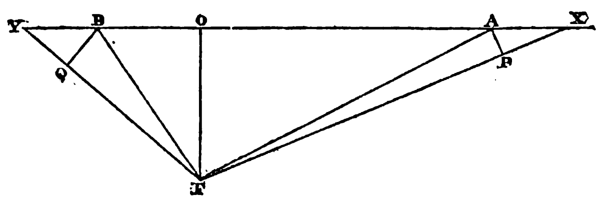
$$c(t_3-t_2)\sin\Phi=a(t_2-t_1)\sin(\mathrm{B}-\Phi).$$

Expanding, and solving for tan Φ, we finally obtain

$$\tan\Phi=\frac{a(t_2-t_1)\sin\mathrm{B}}{c(t_3-t_2)+a(t_2-t_1)\cos\mathrm{B}} \quad . \; . \; . \quad (3)$$

Having found Φ by means of this equation, we can then determine v from either (1) or (2).

Given the Horizontal Velocity of an Earthquake at any two points, and its absolute velocity; to find the position of the focus from which it has proceeded.



Let A and B be the points under consideration, and for simplicity suppose them to lie at opposite sides of the unknown focus F, and in the same vertical plane passing through F. [These suppositions are only made to simplify the figure, but do not in any way diminish the generality of the result.]

Let AX be the space moved through on the surface of the ground at A in the unit of time, and equal v the horizontal velocity, and let BY be the velocity at B and equal v'. Letting fall the perpendiculars AP and BQ; PX and QY will denote the spaces described by the earthquake in a *radial* direction (FX or FY); they are therefore equal and each is the *absolute* velocity of the earthquake $=$V. Hence

$$\cos \mathrm{AXF}=\frac{\mathrm{V}}{v} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (1)$$

$$\cos \mathrm{BYF}=\frac{\mathrm{V}}{v'} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

Therefore since v, v', V are all known quantities, the angles A X F and B Y F are also known, and therefore the lines X F and Y F may be drawn, and their intersection F will give the required position of the focus.

Corol. 1. If the position of the point O, at the surface, from which the earthquake appears to radiate, be known; one velocity will determine the depth of the focus.

Corol. 2. Independently of any diminution in the *absolute* velocity of the earth-wave, the apparent horizontal velocity will diminish rapidly, approaching indefinitely the limit V. This is evident from the geometrical considerations arising from the fact that PX is always equal to QY.

It is obvious, then, that by the establishment of these very simple and inexpensive seismometers, and connecting them galvanically (as respects their registration) by methods now become both familiar and simple, we may get good first approximations to one of the most important questions of the physics of our globe—a knowledge of the depth from which earthquake impulses arrive.

Simple and inexpensive, however, as the apparatus recommended is, its establishment in the only way in which it can be of much real use, namely by connected distant stations, involves the choice of seismic areas fitted for the purpose, and the support and aid of governments, if not for outfit, at least for appointment of observers, and police protection of stations and wires. It is to be hoped that even these may not be withheld as the advancing knowledge of the importance to physical geology of seismic research becomes better understood and diffused. Meanwhile a still simpler form of rough seismometer, suited to the resources of distant and isolated observers, may be with advantage, perhaps, pointed out,—and also an indirect method, by which the depth of earthquake origin may be approximated, without the use of seismometers of any sort. The form of seismometer about to be described is most applicable to seismic districts where the angle of wave-emergence is not steep, *i. e.* where the shocks are usually nearly horizontal.

If any homogeneous, parallelopiped, or rectangular prism, standing on end, upon a level surface, be upset by its own inertia, the supporting surface being suddenly moved beneath it, in the direction of its own plane (as by the horizontal component of an earthquake shock), it may be shown that the velocity of the surface must be

$$V^2=\frac{4}{3}g\sqrt{a^2+b^2}\times\left(\frac{1-\cos\theta}{\cos^2\theta.}\right)$$

where a is the altitude of the solid, b its diameter of base, and θ the angle formed by the side and a line drawn through the centre of gravity to the extremity of the base, and $V^2=2gh$.

This velocity is independent of the density or material of the *solid*, because the oversetting force, being its own inertia, is always proportionate to the density. With a given velocity V, therefore, it is possible to assign the dimensions a and b such, that it shall be *just overset*; and with this velocity another solid, having θ greater, shall remain unmoved,—assuming always that friction upon the supporting surface gives sufficient adhesion to cause the solid to upset, and not to slide (partly or wholly) without upsetting.

If in place of a square prism like a wall, the solid be a right cylinder, such as a pillar, the diameter of whose base, as before, is b; then

$$V^2=\frac{15b^2+16a^2}{12a^2}\times g\sqrt{a^2+b^2}(1-\cos\theta);$$

and from this very simple expression for the horizontal velocity, for which I am indebted to my friend Professor Haughton, it is easy to construct a seismometer of the greatest simplicity, that (in the absence of better means) shall give, within a narrow limit, the actual velocity of shock.

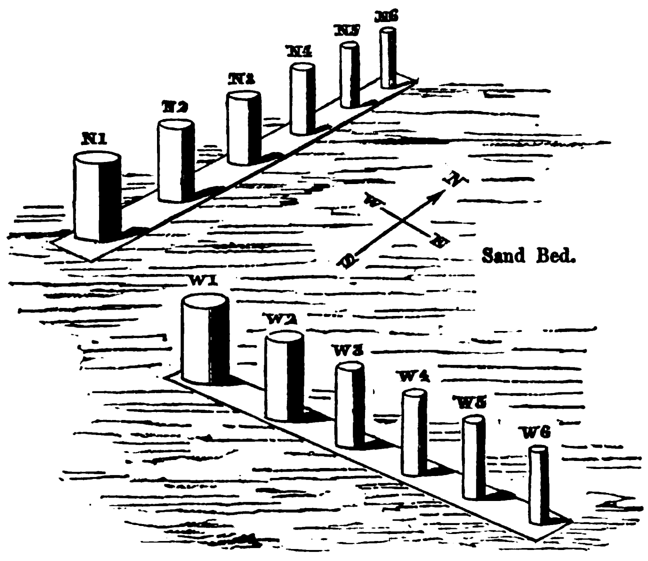
Let there be constructed two similar sets of right cylinders, say each set, six to twelve in number, all of equal height (a) and of the same sort of material, but varying in diameter in each set, with a uniform decrement from the greatest to the least.

Convenient dimensions for earthquake observations of *mean* intensity, will be such, that the cylinder of largest diameter shall have its altitude equal to three diameters, or $b=\frac{a}{3}$, and that the cylinder of least diameter shall have its diameter one-third of that of the greatest one, or $b=\frac{a}{9}$. Any number of cylinders of intermediate diameters may be interpolated between; and the greater the number, the more accurate the instrument becomes. A series of six to ten in each set will, however, be sufficient for any purpose. For observation of shocks of extreme violence, larger diameters, in proportion to altitude, should be chosen for all the cylinders.

The material of the cylinders is not important, cast iron, stone, pottery, or other substances at hand, whose *arrises* will not crumble away by being overthrown, may be used; but no material will be found more convenient than some hard heavy wood, of uniform substance, straight grain, and equable specific gravity, from which the cylinders can be formed in the lathe, and their bases brought perfectly square to the axis with facility.

Upon any horizontal and solid floor let two planks be placed, as in fig. 6, with their directions in length respectively lying N. and S. and E. and W.,

Fig. 6.



each plank to be about 3 inches in thickness, and in width equal to the diameter of the largest cylinder, and its length such that the set of cylinders, when placed upright and equidistant thereon, shall have a space greater than the altitude between each. Thus, if the cylinder of largest diameter have $b=0{\cdot}5$ of a foot, the length of plank will, for a set of six, as in the figure, be about 12 feet. These base-planks being *fixed*, level, and solid, the floor is to be levelled up to their upper surfaces with dry sand, and the two sets of cylinders adjusted to their places, one set running in an east and west, and the other in a north and south direction, so that in whatever direction the horizontal component of shock may move, the overthrown cylinders, of one or the other set, shall fall transversely to the lengths of either of the plank bases, and, lodging on the sand-bed, *remain exactly in the position as to azimuth in which they were overthrown.* If now a shock of any horizontal velocity capable of overthrowing some of the cylinders, but not all of them, arrive, it will throw down at once all the narrower ones, and up to a certain diameter of base. For example, suppose a N. and S. shock, of such velocity as to overthrow W 6, W 5, and W 4, leaving W 3, W 2, and W 1 standing; then V will have been *greater* than the velocity due to the overthrow of W 4, and *less* than that due to the overthrow of W 3, and, within those limits, may be found from the preceding equation. The cylinders here overthrown, W 6, W 5, and W 4, will be found with their axes lying N. and S., at rest upon the sand-bed. The cylinders N 6, N 5, and N 4, will be also overthrown; but in this case they will fall in the line of their own plank bases, and *may* roll and so give no indication as to direction of shock in azimuth. Hence the necessity for two sets of cylinders; one set, however, will be sufficient, if space enough be provided between the cylinders, and if each be placed upon a cylindrical and separate basis of a diameter equal to its own, and in height equal to the depth of the sand-bed.

This form of instrument, then, is capable of giving approximate determinations of—

1st. The velocity of the horizontal component of shock, neglecting the vertical component, which may be done where the angle of emergence is not great.

2nd. The azimuthal direction of the horizontal element of shock.

3rd. Its absolute direction of primary movement, viz. the direction of translation of the wave, which always coincides with the direction of molecular movement of the elastic wave itself, in the first half of its complete phase: *e. g.*, if the wave show a N. S. azimuth, by the line of direction of axes of the overthrown cylinders, and these be thrown to the northward, then the wave has traversed from S. to N.

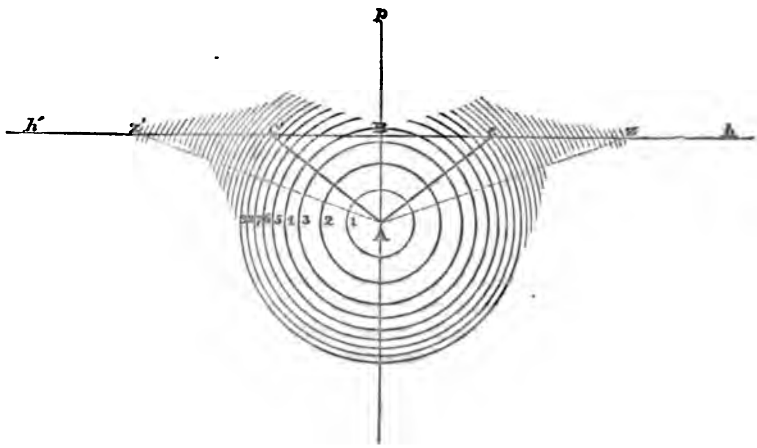
4th. The exact time of the transit of shock may be also indicated if the narrowest cylinders, N 6 and W 6 be connected with a clock, so as to stop it at the moment of overthrow by the very simple means which I have pointed out in the 'Admiralty Manual' (art. "Earthquake," sec. vii., p. 208, 2nd edit.), inasmuch as, by hypothesis, the narrowest cylinders will be *always* overthrown.

A single cylinder or prism, however entirely distinct from either seismometrical set, and of even less stability as respects shock, may be with advantage adopted as the means for stopping the clock by the above method, which is capable of giving the time to within 0·1 of a second.

It is obvious that the application of the principles involved in this form of seismometer to observations made upon the recent overthrow of walls, columns, or other such objects to be found in regions which may have been visited by earthquakes, is capable of giving also approximate measures of velocity and direction of shock. This class of seismic observation will, I hope, be found more fully developed elsewhere.

In conclusion, one other method of indirect seismometry remains to be explained, which does not require the aid of any seismometric instrument. The facts upon which this method depends have been alluded to in the Report on Earthquakes of 1850, p. 35. It has been long observed that, in *extensive* surfaces of country that have been exposed to the effects of shock, certain zones or areas of surface, more or less irregular, present themselves, within which the destructive effects upon buildings and other objects capable of overthrow are manifested much more intensely, than upon similar objects situated upon other portions of the superficies of the country. These zones of maximum disturbance (as yet ill observed) have been remarked to run in curvilinear directions of surface, to approach more or less, according to the means of (*i. e.* the objects afforded for) observation, to closed curves, and to be wholly distinct from those variations of destructive agency, irregularly *parsemé* over large shaken areas, which depend upon differences of geologic surface-formation, configuration of country, &c., construction of buildings, and many other conditions, which modify the direction and effects of the shock at points often very little removed from each other, and the analysis of which, and extrication of the true primary movement from the entanglement of such minor phenomena, constitute the greatest difficulty of earthquake observation. The physical conditions which give rise to such zones of maximum disturbance are easily explained.

Fig. 7.

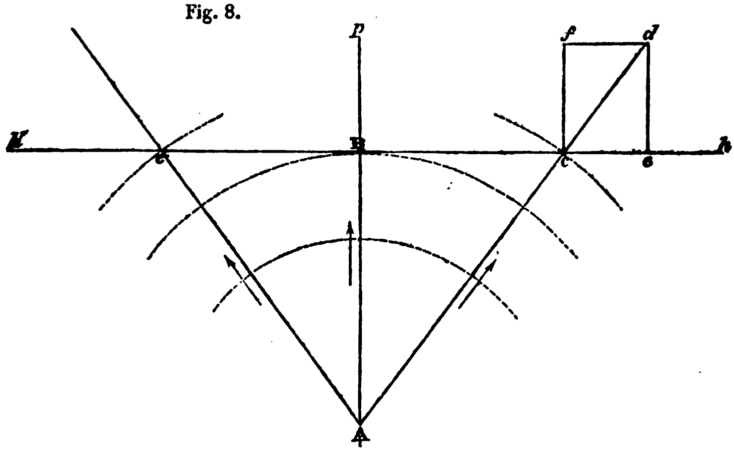


Referring to fig. 7, let *h' h* be the horizon (which we may assume a right line) cut by a vertical plane passing through a great circle of the earth, and through A, the centre of impulse of the earthquake. The blow from this origin is propagated outwards in all directions, through the elastic mass of the earth (here assumed homogeneous), in spherical concentric shells, which the circles 1, 2, 3, 4, &c. denote, at similar phases of the wave. The elastic wave starts from the impulse with one normal and two transversal vibrations. Its *vis viva* must remain constant, and (in the same medium its dimensions being very great) the velocity of translation also. The mass in wave-movement, at any moment of its transit, is therefore the same, and the thickness of each successive spherical shell decreases from the centre of impulse as the square of its mean distance. This is the measure of the normal excursion of any particle, from any given phase of the wave, in its passage outwards, to the recurrence of the same phase, and is also the measure of the normal intensity of the shock, or that in directions AB, AC, AZ, &c. Neglecting for the present the effects of the transversal wave, the normal intensity or *direct* overthrowing power of an earthquake shock varies inversely as the square of the distance from origin. But the *surface* capability of the shock to overthrow buildings, &c. depends not only upon its intensity, but upon the direction of its movement with respect to the horizon. A shock perfectly vertical has no tendency to overturn the *walls* of a house, though it may bring down the roof or floors. Now it is obvious from the figure, that as the wave passes outwards from the origin, A, it reaches the earth's surface vertically at B, the point in the prime vertical, pA, directly over the same; and that as it travels outwards, it emerges at the surface with angles more and more nearly horizontal; the angle of emergence being the same at all points of any coseismal line, all such lines being, on the assumption of homogeneity, concentric circles round B (like those upon a pond into which a stone has been thrown).

So far as the *direction* of wave-motion is concerned, therefore, its power to overturn buildings is greater the further it has travelled, or the greater the radius of the coseismal circle from B; but its *energy* has been shown to be inversely as the square of the distance (not upon the earth's surface, but in the normal). Hence it follows that there must be some given distance upon the surface around B at which the combined effect, of most advantageous direction and lessened energy, shall produce the most destructive effects upon buildings, &c., or a point, C, intermediate to B and Z, or Z′ supposed at any indefinite distance, at which the shock will be, in this respect, a maximum. The radius BC will then describe a coseismal circle upon the earth's surface, which will be a zone of maximum disturbance.

Conversely, if we can trace by observation of the shaken country such a zone, or ascertain three points in its circle, we can find the centre of the circle or the point B, which is plumb over the centre of impulse beneath; and if we have ascertained the angle of emergence that produces the maximum effect (and which is a constant), we can then calculate the depth of the centre of impulse, A, beneath the earth's surface.

Fig. 8.



Referring to fig. 8, let A be, as before, the centre of impulse; B the point upon the earth's surface (supposed a plane), in the prime vertical pA, directly above it. It is required to find a point, C, at which the horizontal overthrowing effects of an impulse in the direction AC, whose intensity varies inversely as the square of the distance, shall be a maximum.

Produce AC to *d*, and complete the parallelogram of forces, *f d* being parallel to the horizon.

Let $BA=a$, the depth of origin;
$BC=r$, the radius where the horizontal force is a maximum
$AC=$the normal due to this radius.
The angle $Cde=BAC=\theta$.

Then the force at C in the direction AC is $\frac{1}{a^2+r^2}$; and that in the direction of the horizon is $\sin\theta\times\frac{1}{a^2+r^2}$; and as

$$\sin\theta=\frac{r}{\sqrt{a^2+r^2}}$$

we have

$$\sqrt{a^2+r^2}:r::1:\frac{r}{\sqrt{a^2+r^2}}$$

and

$$\frac{1}{a^2+r^2}\times\frac{r}{\sqrt{a^2+r^2}}=\frac{r}{(a^2+r^2)^{\frac{3}{2}}}\text{ a maximum.}$$

Differentiating,

$$(a^2+r^2)^{\frac{3}{2}}\times dr-\tfrac{3}{2}(a^2+r^2)^{\frac{1}{2}}\times 2r^2=0.$$

$$a^2+r^2=3r^2$$

$$r=\frac{a}{\sqrt{2}}=\frac{a\sqrt{2}}{2}.$$

The angle CAC′ is therefore very nearly 70° 31′ 43″, which is the angle of the cone whose base in the horizontal plane limits the zone of maximum disturbance; and as the angles at B are right, the angle of emergence BCA=54° 44′ 9″, and the sides of the triangle, BC : BA : AC, are to each other in the ratios of

$$1:\sqrt{2}:\sqrt{3}.$$

Hence we arrive at the very simple practical rule.

Having found the coseismal zone of maximum disturbance by observation, or three points in it, and the centre of the circle passing through them, the depth below the surface, of the origin or centre of impulse, will be the diagonal of the square whose side is equal to the radius of the given circle.

Within certain approximate limits, then, the application of this rule is capable of giving some information upon that great object of research, to which, above all others, seismological investigation points, namely, the depth beneath our surface from which such impulses reach us, and, by consequence, that at which active volcanic forces are in operation within our planet.

This method can scarcely be applied in very mountainous regions, unless both mountain-formations and seismic energy be developed upon a grand scale, as in Mexico and South America; and in every case the observer will find himself encumbered and perplexed by the interference of many minor circumstances of disturbance to mask and render difficult his observations. These, however, should not prevent our bearing the method in mind whenever favourable conditions present themselves for its use.

In the present state of the theory of wave-movements in elastic solids, it cannot be said to be experimentally certain, that the energy of the wave, in the normal, does diminish with the square of the distance. Another view of the primary conditions of its motion would make it diminish directly as the distance, in which case it may be proved that the angle CAC′ of the coseismal cone of maximum disturbance will be 90° and constant, and hence that the depth of the origin (upon that hypothesis) will be always equal to the radius of the circle of maximum disturbance. It would be out of place here to enter further into the physical discussion of this question, except by referring to Herschel (art. "Light," 'Encyc. Metrop.' vol. iv. paragr. 18. p. 578) and to the various papers of Cauchy, Wertheim, Stokes, Airy, Haughton, and Maxwell on the subject.

I have stated that in the preceding investigation the effects of the transversal wave are neglected. In the observation of actual earthquake phenomena, this may probably be safely done as respects all points that are at considerable distances from the centre of disturbance. The normal and transversal waves, starting at the same instant, appear to travel with unequal velocities. They part company; and their distance becomes greater, and the interval larger between their arrivals, the further they have both travelled. Were we enabled, therefore, to ascertain the precise velocity of the normal wave, and the exact interval of time between the arrival at a distant point of the normal and transversal waves, we could still by another method arrive at the distance from which they had come, and therefore at the depth of the origin of impulse, if the angle of emergence at one point were known. According to Cauchy, the velocity of transit of the normal is to that of the transversal wave as $\sqrt{3} : 1$ in media of unlimited mass; and Wertheim's modified formulæ for elastic bodies fix it as $2 : 1$. My own experimental observations with the seismoscope have proved to me that the separation of the two waves can be noticed, and the interval of time measured upon even very moderate ranges of wave-transit, not exceeding a few miles; and the observations of earthquake shocks indicate that *one cause* of the tremors that usually *succeed* the main blow, is the later arrival of the normal wave, whose amplitude at considerable distances from the origin is always small.

However this may be, it is certain that in all earthquakes the real mischief and overthrow, at places pretty far removed from above the centre of impulse, are done by the blow from the normal wave, which appears to come first; hence the main observable effects are those of the normal, and we are justified and enabled, *in such localities*, to neglect the transversal. But within a considerable circle of area, whose boundary is evanescent, and whose centre lies at the point B (figs. 7, 8), right above the origin, the actual effects of the transversal wave are very formidable, and can never be neglected.

The ground beneath an object so situated, such as a house or pillar (as the distance from the origin to the surface is the minimum range of emergence, or shortest possible, and therefore its energy the greatest), is almost at the same instant thrown nearly vertically upwards by the normal wave, and at the same moment rapidly forced forwards and backwards horizontally in two directions orthogonal to each other; and this combined movement, which is that called "vorticoso" by the Italians and Spanish Mexicans, is one that nothing, however solid and substantial in masonry, &c., can long withstand.

Hence it follows that, within the zone of maximum disturbance which we have treated of, and occupying its central region, we shall always find an area, more or less circular, also of great overthrow and destruction, though presenting entirely different characteristics as to the manner of overthrow of the buildings, &c. This middle region may therefore be sought for as a further directrix to the point B over the centre of impulse. It may be necessary to remark that this combined movement, due to the two transversal waves, and *limited* to a region closely above the prime vertical passing through the centre of impulse, must not be confounded by any misconception of the phrase "vorticoso," with that false notion of vorticose shock, such as was presumed to have twisted the Calabrian obelisks, &c., the real nature of whose displacement I indicated in 1846. (Trans. Roy. I. Acad. vol. xxi. part 1. See also 1st Report Trans. Brit. Assoc. 1850, pp. 33, 34.)

In conclusion, I would repeat my conviction that a further expenditure of labour in earthquake catalogues of the character hitherto compiled, and alone possible from the data to have been compiled, is now a waste of scientific time and labour. The main work presented for seismologists in the immediate future, must consist in good observations, with seismometers advantageously placed at sufficiently distant stations, and galvanically connected as to time; and in the careful observation of the traces left by great shocks (when of recent occurrence) upon buildings and other objects artificial and natural, with a view to determining the nature of the forces that have affected them, aided by the resources of the physicist and mathematician.

Amongst the unknown regions of our world, as respects the recurrence of earthquakes and their phenomena, the most prominent are Central Africa, Abyssinia, Madagascar, Northern Asia, and the north-west of North America. For observations of the last, the new settlements about being formed at Vancouver's Island will, no doubt, offer great facilities, as well as future access to the great Aleutian chain of volcanoes and their seismic zone.

I reserve for the Appendix a few observations, upon great sea waves and certain ill-understood phenomena, which could not systematically find place in this Report.

APPENDIX.

No. I.

(P. 48.) The following table of some of the men and events upon which the progress of human knowledge and discovery and the diffusion of mankind have depended, may serve to illustrate the relations that these bear to the expanding character of the catalogue:—

	Date. A.C.
Yards for spreading ships' sails invented	1200
Silver money.—Anchors.—First sea fight	700
Amber and tin carried by Phœnicians from the Baltic and England to the Levant..	600
The sounding-line used at sea.—Maps in use.—Multiplication table.—Moon's eclipses calculated.—Pythagoras	500
Trireme galleys in use.—The burning-lens known	400
War chariots in Gaul.—Arrack brought from India into Europe.—Electricity noticed.—Hemp, cordage (?), and sails (?).—Aristotle	300
Clepsydra.—Ballistæ.—Silver coin at Rome.—The olive.—Chinese wall.—Hannibal	200
Lucullus introduces cleansing soap from Gaul—sal-ammoniac from Egypt.—Solar year fixed	100
Christ born.—Seneca.—Strabo.	A.D.
First sea voyage to India, probably	3
Stained-glass windows—the vine—Saw-mills—Monachism—all in Germany	300
The Western Empire.—Public lights at Antioch.—Church bells The dark ages commence.	400
Franks Christianized.—Silk-worms in Europe	500
Hops.—Quill pens.—Latin disused.—Mahomet I.	600
Charlemagne names the days and months	800

	Date A.D.
Oxford and Cambridge Universities.—First book.—Alfred the Great	900
Arabic notation in Europe.—Wheel clocks in use.—The first crusade	1100
The three last crusades.—The sugar cane in Sicily.—Coal as fuel.—The corporation of London.—The Popish inquisition.—Saladin	1200
English parliaments.—English in our law courts.—Gunpowder.—Cannon.—Mariners' compass.—Printing.—Engraving.—Oil painting.—Coaches.—Roger Bacon.—Wiclif.—Tamerlane	1400
America.—Columbus's four voyages, from 1492-1504.—Cape of Good Hope.—Indian Sea.—Vasco di Gama, 1499.—John and Sebastian Cabot, 1497.—Public road and bridges through Western and Southern Europe.—Luther.—The Reformation	1500
Logarithms.—Watches.—Barometer.—Telescope.—Mercator.—Italian book-keeping.—Jupiter's satellites discovered.—Copernicus.—Galileo.—Magelhaen's voyage, 1520.—Drake's voyage, 1580	1600
Royal Society.—Newton.—Sextant.—Chronometers.—Greenwich Observatory.—Tea into Europe.—Clive.—Penn.—South Sea Company.—Cod and herring fisheries.—Semaphore.—New style calendar	1700
Anson's voyage (1744)	
Cook's last voyage (1779)	
La Perouse (1788)	
Vancouver (1795)	
Watt's steam engine (1796)	
Napoleon.—Nelson.—Embassies to China and Japan.—Vaccination.—Gas lights.—Life-boats.—Public docks.—Public coaches and diligences.—Newspapers abundant	1800 to present date.
Steam navigation.—First steam-ship 'Savana' crosses the Atlantic, 1819.—Railway system, 1820.—Electric telegraph, 1830.—Law of tides—of storms.—Gold in California—in Australia	

No. II.

(P. 57.) From the interest that belongs to observations of earthquakes in the Southern Hemisphere, hitherto so seldom recorded, I append the following extracts from the letter of an intelligent friend, referring to the New Zealand shock of 1854-55, written very soon after the event. The writer is a civil engineer.

The New Zealand Earthquake.

"Wellington, 23rd January, 1855.

"Whilst sitting reading and talking at 8.50 P.M., I felt the house (which had been shaking with the occasional N.E. gusts so usual at Wellington) give a very extraordinary shake, which seemed to continue, and was accompanied by a fearful noise. I at once jumped up, rushed, as well as the violent motion would permit me, into the front garden, the motion increasing in violence, accompanied by a roaring as if a large number of cannon were being fired near together, and by a great dust caused by the falling chimneys. The motion at first was a sharp jerk back and forwards in a N.E. and S.W. direction, increasing in extent and rapidity, until I got into the garden—say 25 seconds; it was then succeeded by a shorter and quicker motion at right angles, for nearly the same time, still increasing, but appearing to be perfectly in the plane of the horizon. This was followed by a continuation of both, a sort of vorticose motion, exactly like the motion felt in an ill-adjusted railway carriage on a badly-laid railway at a very high speed, where one is swayed rapidly from side to side. This was accompanied by a sensible elevatory impulse; it gradually subsided; and the above, constituting the first and greatest shock, lasted altogether, I should say, 1′ 20″ or 1½′ *at Wellington*. The earth continued to vibrate all night like the panting of a tired horse, with occasional shocks of some violence, decreasing in frequency and violence towards morning, and nearly all in the N.E. S.W. direction, some of them a single jerk back and forwards like that of one railway carriage touching another, but generally they were followed by a vibration gradually decreasing. These lasted, with increasing intervals, until I left Wellington on the 11th April. For the first week after the first shock, the vibration never wholly ceased. All the brick buildings in Wellington were overthrown, or so injured, as to necessitate their removal; the Hutt Bridge was thrown down; the hill-sides opposite Wellington were very much shaken, as evidenced by the many bare patches with which they were chequered fully to the extent of one-third of their surface, whence trees had been shaken off: this range, particularly its lower portion, appeared to have been the most shaken. It is called the Rimatuka Range, and divides Port Nicholson and the basin of the Hutt from the Warumrapa Valley, where the earthquake was felt with greater violence than at Wellington, the ground having opened in many places 8 or 9 feet, and sunk in one place for 300 yards square to a depth of 8 or 9 feet. The cracks are very frequent, and at first were of considerable depth (deemed unfathomable, because people could not see their depth), perhaps 15 or 20 feet in depth, and extending for many hundred yards. Ploughed ground and mud, dry river- or pond-beds were thrown up into all sorts of undulations like a short cross sea, the ridges in some cases 2 feet in height, the prevailing direction of cracks and ridges being generally at right angles to the apparent line of force, N.E. S.W. The strata about Wellington and the Rimatuka are a sort of shale and clay-slate, all broken into pieces not bigger than road-metal, with yellow clay joints; and in places where the overlying clay has been cut through by roads, one can see the cracks caused by former earthquakes filled up by a different-coloured material. I should mention the great sea-wave which came in immediately after the first shock, about 5 feet higher than the highest tide inside the harbour, and 12 feet higher outside; the tide (*i. e.* water-surface) continued ebbing and flowing every 20 minutes during the night, and was most irregular for a week, ebbing further than ever known before. After that time it became more regular; and now the ebb and flow is the same as before the earthquake; but since that, it does not come at high-water within 3 or 4 feet of its former height, proving that the whole southern part of the northern island has been raised, the elevated portion commencing at Wangarner, on the west coast, and going round to Castle Point on the east, where it terminates. The vertical elevation is greatest at the Rimatuka Range, outside Port Nicholson, and becomes *nil* at the above-mentioned points. The shock was felt at Nelson almost as badly as at Wellington, slightly at Canterbury and Ahurii. It was most violent on the sides of hills at these places, and least so in the centre of the alluvial plains.

"The great shock continued at any one point longer, the further it had diverged from its apparent centre of action opposite Wellington, and became less violent, the motion being slower and not to such an extent. This I think plainly proves (if any thing were wanting to prove) Mr. Mallet's wave theory: any person of the slightest perception experiencing the shock and comparing the statements of persons who had felt it in different places could come to no other conclusion. I do not think the thermometer or barometer was affected; I had no opportunity of observing myself; but so I heard; nor was the compass acted on more than was due to the motion.

"The captain of the vessel I went in to Ahurii was outside Port Nicholson, lying-to in a gale, and thought his vessel had struck, and was dragging over a reef of rocks; the next morning he passed hundreds of dead fish all of one sort, a species of ling, whose habit it is to lie on the bottom. The shock was also felt by the 'Josephine Willis,' 150 miles off the coast. I only regret, time and want of means prevented my making more accurate observations, and even giving you those I did make in greater detail. W. C. B."

[The direction of primary shock mentioned by the writer is in the line of the mountain-chain, reaching from the interior down to Wellington, and also in that pointing to Tonguro and other volcanic cones.—R.M.]

No. III.

BIBLIOGRAPHY OF EARTHQUAKES.

At the period of publication of the Second Report on Earthquakes, it was my intention to have prepared a complete Bibliography of Earthquakes, the want of some such index having been much felt by myself, at former periods. Subsequently, however, I found that my friend, Professor Perrey, of Dijon, had had such a work in progress for some years; and he has since published his Bibliographical Catalogues in the 'Mémoires de l'Académie Imp. de Dijon,' vols. xiv. and xv. 2nd ser., for 1855-56, which contained, in alphabetical order, one thousand eight hundred and thirty-seven different works on Seismology. Even yet, however, the store of literature in this speciality are not completely taken stock of. I have hence deemed it best simply to publish, in the following lists, such works as I have found in the several European libraries named at the head of each separate list, along with one in which works, that from various sources have met my eye, are collected. The materials thus given will be, I should hope, of some present service to scientific travellers abroad; and such portions as are new can be intercalated with future editions of more perfect catalogues, such as M. Perrey's. The following is the order of the library lists:—

1. British Museum.
2. Royal Society of London.
3. Trinity College, Dublin.
4. Royal Library, Berlin.
5. Naturforschenden Freunde of Berlin.
6. Royal School of Mines, Berlin.
7. Library of the University of Göttingen.
8. Royal Library of Munich, Bavaria.
9. Royal Library of Dresden, Saxony.
10. Library of Gand, Belgium.
11. Library of the Mineralogical Museum, Naples.
12. Works on Seismic and Volcanic Subjects from various sources.

Library of the British Museum.

Verhail van de Groote Aertheninghe binnen Mantua in Lulio 1619. 4to. Antwerpen. No date.

Account of the late Earthquake in Jamaica. 8vo. London, 1693.

Supplement to the Bishop of London's Letter on occasion of the late Earthquake. 8vo. London, 1750.

Serious Thoughts on the Earthquake at Lisbon. 8vo. London, 1755.

Reflections, Physical and Moral, upon the uncommon Phenomena which have happened from the Earthquake at Lima to the present time. 8vo. London, 1756.

A short and pithie Discourse concerning the engendering, tokens, and effects of all Earthquakes in generall. By T. T. 4to. London, 1580. (Black letter.)

A most true relation of a very dreadfull Earthquake which began upon the 8 December, 1612, and still continueth in Munster, in Germanie. 4to. London, 1612. (Black letter.)

Vera Relatione del Spaventevole Terremoto nelle provincie di Calabria citra et ultra. 4to. Roma, 1638. Also editions in Latin, Neap. 1638; Angl., London, 1638.

Sopra il Terremoto Lezioni tre. 4to. Spoleto, 1732.

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Strange News from Oxfordshire; being a true and faithful account of a wonderful and dreadful Earthquake that happened in those parts, September 17, 1683. Folio.

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A Philosophical Discourse of Earthquakes, occasioned by the late Earthquake, September 8, 1692. By C. H. 4to. London, 1692.

A true and perfect relation of the Earthquake at Port Royal in Jamaica, 7 June, 1692. Folio. London.

A full Account of the late dreadful Earthquake at Port Royal in Jamaica, June 22, 1692. In two letters from the minister of that place. Folio.

A sad and terrible relation of the dreadful Earthquake which happened at Jamaco [*sic*]. 12mo. London, 1692.

A Practical Discourse on the late Earthquakes, with an Historical Account of Prodigies and their various effects. By a Reverend Divine. 4to. London, 1692.

Epistola ad Regiam Societatem Londinensem, qua de nuperis terræmotibus disseritur et

veræ eorum causæ eruuntur. 4to. London, 1693. Proposes to account for earthquakes occurring on astrological grounds.
An account of the late terrible Earthquake in Sicily. Done from the Italian copy printed at Rome. 4to. London, 1693.
The Earth twice shaken wonderfully; or an analogical Discourse of Earthquakes. By I. D. R. [Rouffional], French minister. 4to. London, 1693–94. 47 pages.
The General History of Earthquakes. By R. B. 12mo. London, 1694.
A full and dismal Account of an Earthquake that happened in Batavia, 28 February, 1700. 12mo. London.
A true and particular Relation of the Earthquake which happened at Lima, the capital of Peru, the 28 October, 1746; with a description of Callao and Lima before their destruction, and the Kingdom of Peru in general. 8vo. London, 1748. (Erased in Catal.)
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A Narrative of the Earthquake and Fire of Lisbon. By Antonio Pereira, of the Congregation of the Oratory, an Eye-witness thereof. Translated from the Latin. 8vo. London, 1756.
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Dolorosa Tragœdia representata nel regno di Catania, &c. 4to. Cataniæ, 1695.
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Bridges' Annals of Jamaica. (The great Jamaica Earthquake.)
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A Philosophical Discourse of Earthquakes, occasioned by the late Earthquake of 8 Sept. 1692. By C. H. 4to. London, 1693.
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Oratio in recentem Terræ motum Germaniæ utriusque terrorem, anno 1640, 4 Aprilis, post tertiam matutinam. A Ion Haleno Canonico. 4to. Col. Agrip. 1640. 41 pages.
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A Catalogue of Earthquakes from the earliest Times of the Jews and Phylistines down to that when the Emperor Henry IV. made war with Pope Pasquale II. (Vide date.) Few precise dates given; chiefly a mass of churchmen's superstition.
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The Scripture Account of the Cause and Intention of Earthquakes; in a Sermon preached at the Old Jewry, March 11, 1749–50, on occasion of the two shocks of an Earthquake, the first on February 8th, the other on March 8th. By Samuel Chandler. London, 1750.

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2. „ Beschluss der Beiträge, ib. 1794.
3. „ Beschreibung einer Sammlung von meist vulkanischen Fossilien die Déodat Dolomieu im Jahre 1791, von Maltha aus nach Augsburg und Berlin versandte. Fol. Frankf. a. M. 1797.

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Relazione giornaliera del tremuoto seguito in Barga l'anno 1746, nel mese di Luglio. Compilata dal dott. F. Tallinucci. (Communication of M. Pilla to M. Perrey.)
Courejolles on Earthquakes. Journal de Physique, an. 10. Pluviore.
Catalogue des Tremblements de Terre en Chine. Par E. Biob. Ann. de Chimie, 3 ser. vol. ii. p. 372.
Sopra......, Sur les petits mouvements apparents observés dans les murs et les grands instruments d'observatoire de Modena. Par M. J. Bianchi. 4to. Modena, 1837.
Ueber das Erdbeben in den Rhein, &c. vom Feb. 1828, von P. C. Egen. Pogg. Ann. for 1828, part ii. pp. 153–176. An important memoir.

Beuther, Compendium Terræmotuum. Strassburg, 1601.
Bernhertz, Terræmotus. (A Register of Earthquakes.) Nürnberg, 1616.
Dr. Vincenzio Magnati, Earthquake of Naples, 1688.
Bertrand, Mém. hist. sur les tremblemens de terre. La Haye, 1757.
Bertholon, Jour. de Phys., vol. xiv.
Vivenzio, Istoria e teoria de' terremuoti avvenuti nella provincia della Calabria, &c., di 1783-1787. Napoli, 1788.
Cotte, Tab. Chron. de princip. Phénom. Météorologiques, &c. Journal de Phys., vol. lxv.

No. IV.

CATALOGUE OF PERREY'S MEMOIRS.

The immense and long-continued seismic statistics of Prof. Perrey are scattered throughout a multiplicity of Journals of various Learned Societies and elsewhere, and many of them with difficulty accessible in Great Britain.

The author has, at my request, favoured me with the following complete Catalogue of his seismological labours, which it may be serviceable to place in a collected form for reference.

Perrey (Alexis), Chronique seismique. 1 vol. 8vo, MS. 1ère rédaction.
——, la même. 9 vols. 4to, MS.
——, Tremblements de Terre dans les différents siècles et aux différentes époques de l'année. Compt. Rend. t. 12, p. 1185–1187, 21 Juin, 1841.
——, Recherches historiques sur les Tremblements de Terre dont il est fait mention dans les historiens depuis le IVe siècle jusqu'à la fin du XVIIIème. Ibid. t. 13, p. 899–902, 2 Nov. 1841.
——, Recherches sur les Tremblements de Terre ressentis à l'Europe et dans l'Asie occidentale de 306 à 1800. Ibid. t. 19, p. 64–646, 26 Sept. 1842. Neuf cahiers seulement m'ont été remis au Secrétariat de l'Institut.
——, Note sur les Tremblements de Terre aux Antilles. Ibid. t. 16, p. 1283–1303, 12 Juin, 1843.
——, Nouvelles Recherches sur les Tremblements de Terre ressentis en Europe et dans les parties adjacentes de l'Afrique et de l'Asie de 1801 à Juin 1843. Ibid. t. 17, p. 608–625, 25 Sept. 1843.
——, Mémoires sur les Tremblements de Terre, en France, en Belgique, et en Hollande, depuis le IVe Siècle jusqu'à nos jours. 1843.
——, Mémoire des Sav. Étr. et Mém. Cour. de l'Académie de Bruxelles, t. 18, 4to. 110 pp. et 2 pl. avec Suppl. MS.
——, le même. 1 vol. 4to, MS. 1ère rédaction avec addit. MS. de M. Quetelet.
——, Liste des Tremblements de Terre ressentis en Europe pendant l'année 1843. Ibid. t. 18, p. 393–403, 11 Mars 1844.
——, Notice sur les Tremblements de Terre ressentis à Angers et dans le Dép. de Maine et Loire. Bull. de la Soc. industr. d'Angers, t. 15, p. 172 et suiv., 1844. Tir. à part, 8vo de pp. 7.
——, Liste de Tremblements de Terre ressentis en Europe pendant l'année 1844. Avec Supplément pour l'année 1843. Mém. de l'Acad. de Dijon, 1843–44, p. 334–342, et comprend t. 20, p. 1444–1452, 12 Mai 1845.
——, Sur les Tremblements de Terre de la Péninsule Scandinave. Voyages en Scandinavie de la Com. Sc. du Nord. 6 div. Géog. phys. t. 1, p. 409–469. Tir. à part. Paris, 1845. 8vo de pp. 65, avec Suppl. MS.
——, Sur les Tremblements de Terre dans le bassin du Rhône. Ann. de la Soc. d'Agric. de Lyon, t. 8, p. 1845. Tir. à part. 8vo de pp. 82, 1 pl. avec notes additionnelles de M. Fournel, et Suppl. MS.
——, Sur les Tremblements de Terre dans le bassin du Danube. Ibid. t. 9. 1846. Tir. à part. 8vo de pp. 82, avec Suppl. MS.
——, Note sur les Tremblements de Terre en Algérie et dans l'Afrique septentrionale. Mém. de l'Acad. de Dijon, 1845–1846, p. 299–323. Tir. à part. 8vo de pp. 24, avec Suppl. MS.
——, Sur les Tremblements de Terre aux Antilles. Ibid. p. 325–392. Tir. à part. 8vo de pp. 68, avec Suppl. MS.
——, Liste des Tremblements de Terre ressentis pendant les années 1845 et 1846, avec Supplément pour 1844, et indicative Sommaire des autres phénomènes météorologiques. Ibid. p. 393–479. Tir. à part. 8vo de pp. 87.

Perrey (Alexis), Mémoire sur les Tremblements de Terre dans le bassin du Rhin. Mém. des Sav. Étr. et Mém. Cour. de l'Acad. Roy. de Belgique, t. 19, 1847. Tir. à part. 4to de pp. 114 et 2 pl., avec Suppl. MS.

——, La lune exerce-t-elle une influence sur les Tremblements de Terre? Mém. présenté à l'Acad. des Sciences, le 5 Mai, 1847. Compt. Rend. t. 24, p. 822. MS. de 11 pp. en 1 vol. 4to; 1 pl.

——, Note sur les Tremblements de Terre ressentis en 1851. Bull. de l'Acad. Roy. de Belgique, t. 19, part 1, p. 353–396, et Supplément; Ibid. part 2. p. 21–28. Tir. à part.

——, la même, avec Supplément pour les années antérieures. Mém. de l'Acad. de Dijon, 2e sér. t. 2, p. 1–65, 1852. Tir. à part.

——, Mémoire sur les rapports qui peuvent exister entre la fréquence des tremblements de terre et l'âge de la lune. Compt. Rend. t. 36, p. 537–540, 21 Mars, 1853.

——, le même, MS. original avec pl. et 1 vol. gr. in-fol. contenant les tableaux des Secousses de 1801 à 1850, MS.

——, Note sur les Tremblements de Terre ressentis en 1852. Bull. de l'Acad. de Belgique, t. 20, no. 5, p. 39–69, 10 Mai, 1853. Tir. à part.

——, la même, avec Suppléments pour les années antérieures. Mém. de l'Acad. de Dijon, 2e sér. t. 2, p. 7–128. Tir. à part.

——, Note sur la fréquence des tremblements de terre rélativement au passage de la lune au méridien. Compt. Rend. t. 38, p. 16, 2 Jan. 1854. Ce MS. est relié avec le No. auquel j'ai encore ajouté les tableaux inédits fournis à la Commission pour le Rapport de M. Elie de Beaumont.

——, Note sur les Tremblements de Terre ressentis en 1853. Bull. de l'Acad. Roy. de Belgique, t. 21, 1ère part, p. 457–495. Tir. à part.

——, la même, avec Suppléments pour les années antérieures. Mém. de l'Acad. de Dijon, 2e sér. t. 3, p. 1–55. Tir. à part.

——, Circulaire relative à l'Observation des Tremblements de Terre, adressée à tous les Voyageurs. Bull. de la Soc. de Géog., 4e sér. t. 7, p. 419–422, Juin, 1854. Tir. à part.

——, Documents relatifs aux Tremblements de Terre du Chili, avec Appendice sur les Tremblements de Terre dans la province de la Plata. Ann. de la Soc. d'Agric. de Lyon, 1854, 2e sér. t. 6, p. 324–436. 8vo de pp. 206, avec Suppl. MS.

——, Note sur les Tremblements de Terre ressentis en 1854, avec Supplément pour les années antérieures. Bull. de l'Acad. Roy. de Belgique, t. 22, 1ère part. no. 6, p. 526–572, Juin 1855. Tir. à part. 8vo de pp. 49.

——, Sur les Volcans et Solfatares de l'île de Java, renseignement puisé dans les observations récentes des Hollandais. Compt. Rend. t. 42, p. 115–116, 21 Janv. 1837. C'est la traduction d'un article sur une solfatare près de Tj. Aray, par M. Bensen, dont M. Elie de Beaumont n'a pas été le nom.

——, Note sur les Tremblements de Terre ressentis en 1855, avec Supplément pour les années antérieures. 1ère partie, Supplément, Bull. de l'Acad. Roy. de Belgique, t. 23; 2e part., No. 7, p. 23–68, Juillet 1856.

——, la même, 2e partie. Ibid. t. 24; 1ère part., No. 1, p. 68–128.

——, Éruption du Manna Loir aux îles Sandwich. Ann. des Voy. Aout 1856, p. 199–229. C'est la traduction de deux lettres de M. Coan, suivie de quelques remarques sur l'éruption du Vésuve en 1855.

——, Excursion sur quelques Volcans de Java pendant l'été de 1854. Ann. des Voy. Oct. 1856, p. 36–65. C'est la traduction de divers extraits du Mémoire de M. Teijsmann, Bibliographie Seismique. Mém. de l'Acad. de Dijon, 2e série, t. 4, p. 1–112, 1855; t. 5, p. 153–253, 1856.

——, Sur les Tremblements de Terre de la Péninsule Ibérique, Ann. de la Soc. d'Agric. de Lyon, t. 10, 1847. Tir. à part. 8vo de pp. 50, avec Suppl. MS.

——, Note sur les Tremblements de Terre ressentis en 1847. Bull. de l'Acad. de Belgique, t. 5, no. 5, 1848. Tir. à part. 8vo de pp. 7.

——, la même, avec Supplément pour les années antérieures. Mém. de l'Acad. de Dijon, 1847–48. Tir. à part. 8vo de pp. 48. C'est une 2e édition, qui pour tous mes catalogues annuels est publiée dans les Mémoires de l'Acad. de Dijon, et qui est plus complète que la première.

——, Mémoire sur les Tremblements de Terre de la Péninsule Italique. Mém. Cour. et Mém. des Sav. Étr. de la Soc. Belgique, t. 22. Tir. à part. 4to de pp. 145, 2 pl. et Suppl. MS. Le même avait été approuvé par l'Acad. des Sciences de Turin qui m'avait voté l'impression; voy. Notizie istoriche dei lavori della Classe delle Scienze nel corso dell' anno 1845. Cette notice se trouve dans notre collection.

——, le même, MS. 4to, avec Introductions et Considérations inédites.

——, Documents sur les Tremblements de Terre au Mexique, et dans l'Amérique Centrale. Ann. de la Soc. d'Émul. des Vosges, t. 6, 2e cah. 1847. Tir. à part. 8vo de pp. 37, et Suppl. MS.

Perrey (Alexis), Instructions sur l'Observation des Tremblements de Terre. Ann. Météor. de France, 1849, p. 299–311. Extr. gr. 8vo.

——, Communication relative à mes recherches rétrospectives sur les Tremblements de Terre, faite à la réunion de la Soc. Géologique à Épinal le 10 Sept. 1847. Bull. de la Soc. Géol., 2e sér. t. 4, p. 1399–1400.

——, Traduction du Mémoire de M. R. Mallet, intitulé, Sur l'Observation des Tremblements de Terre, avec notes additionnelles du traducteur et suivie de la liste des tremblements de terre en 1848. Ann. Météor. de France, 2e ann. 1850, p. 279–300. Tir. à part.

——, Documents sur les Tremblements de Terre et sur les Éruptions Volcaniques dans le bassin de l'océan atlantique. Mém. de l'Acad. de Dijon, an. 1847–1848. Extra 8vo de pp. 67, avec Suppl. MS.

——, Note sur les Tremblements de Terre ressentis en 1848. Bull. de l'Acad. Roy. de Belgique, t. 16, no. 3, 1849. Extr. 8vo de pp. 8.

——, la même, avec Suppléments pour les années antérieures. Mém. de l'Acad. de Dijon. Tir. à part. 8vo de pp. 48.

——, Documents sur les Tremblements de Terre dans le nord de l'Europe et de l'Asie. Ann. Magnét. et Météor. du Corps des Ingénieurs de Russie, an. 1846, p. 201–236. Tir. à part. St. Petersbourg, 1849, gr. in-4to, à 2 vol., 1 pl.

——, les mêmes, suivis d'une note sur les Tremblements de Terre en 1848. Ann. de la Soc. d'Émul. des Vosges, t. 6, 3e cah. 1848. Tir. à part. 8vo de pp. 71, avec Supplément MS.

——, Sur les Tremblements de Terre dans les Iles Britanniques. Ann. de la Soc. d'Agric. de Lyon. 2e sér. t. 1, 1849. Tir. à part. 8vo de pp. 71, avec Suppl. MS.

——, Note sur les Tremblements de Terre en 1849, avec Suppléments pour les années 1847 et 1848. Bull. de l'Acad. Roy. de Belg. t. 17, no. 3, 1850. Tir. à part. 8vo de pp. 22.

——, la même, avec Suppléments pour les années antérieures. Mém. de l'Acad. de Dijon, ann. 1850. Tir. à part. 8vo de pp. 65.

——, Sur les Tremblements de terre dans la Péninsule Turco-hellénique. Mém. Cour. de Mém. des Sav. Étr. de l'Acad. de Belgique, t. 23, 1850. Tir. à part. 4to de pp. 73, avec Suppl. MS.

——, Note sur les Tremblements de Terre en 1850. Bull. de l'Acad. de Belgique, t. 18, no. 4, p. 291–308. Tir. à part.

——, la même, avec Supplément pour les années antérieures. Mém. de l'Acad. de Dijon, 2e sér. p. 1–36, 1850. Tir. à part.

——, Sur les Tremblements de Terre aux États Unis et au Canada. Ann. de la Soc. d'Émul. des Vosges, t. 7, 2e cah., 1850. Tir. à part. 8vo de pp. 62, avec Suppl. MS.

Desiderata—Ill-understood Phenomena, &c.

Great Sea-Waves.—Perhaps the best account that has yet been given of the phenomena of great sea-waves (due beyond question to earthquake or volcanic movement of sea-bottom), was communicated by Prof. Bache to the American Association for the Advancement of Science, and was reprinted along with a paper "On the Tides of the Atlantic and Pacific Ocean," in 1856, in a separate form by Prof. Bache, at New Haven for private circulation, from which the following are extracts.

On the 23rd of December, 1854, a violent earthquake occurred in the neighbourhood of the Island of Niphon (Japan), the local sea-waves of which wrecked the Russian frigate 'Diana,' anchored in the harbour of Simoda. A correspondent of the 'New York Herald,' writing from Shanghae, states,—"At 9 A.M. on the 23rd of December, weather clear, therm. 72°, barom. 30°, a severe shock of an earthquake was felt on board the frigate, shaking the ship most severely. The shock lasted full five minutes, and was followed at quick intervals by rapid and severe shocks for thirty minutes." At 9h. 3m. A.M. the sea was observed washing into the bay in one immense wave 30 feet high, with awful velocity; in an instant the town of Simoda was overwhelmed and swept from its foundations. "This advance and recession of the waters recurred five times".... "by 2h. 30m. P.M. all was quiet." The log-book of the 'Diana' states that "the disturbance commenced at 9h. 15m., and that the rising and falling of the water in the bay produced a sudden variation of depth from less than 8 feet to more than 40 feet. The frigate was by this laid four times upon her side, once in less than 4 feet of water." Commodore M. C. Perry, U.S. Navy, states,—"That the whole eastern coast of Japan seems to have suffered from this calamity. Yedo itself was injured, and the fine city of Osaka entirely destroyed. At 3 P.M. a fresh west wind was blowing at Simoda. The agitation of the water and the movement of the vessel had become very slow; barom. 29°·87, therm. 10°·5 Reaum. (=55°·63 Fahr.)."

From other sources quoted by Prof. Bache, it appears that on the same day (23rd Dec.), at Peel's Island, one of the Bonin Islands, there was also (the hour not stated) a sudden wave rise of 15 feet above high water, followed by a recession which left the reefs entirely bare. The tide continued to rise and fall at intervals of fifteen minutes, gradually lessening until the evening. Again on the evening of the 25th of December (as to which time there is no account of a second earthquake), the water rose in like manner 12 feet.

The United States Coast Survey, so ably superintended by Prof Bache, possesses stations of observation furnished with self-registering tide-gauges, at San Diego, San Francisco and Astoria, on the Pacific Coast; and Prof. Bache presented to the Association the curves traced by those instruments, in which the comparative heights and times, and the mean heights and times at San Francisco and San Diego, are given; also the tidal curves for both, with the abnormal oscillations superimposed; and lastly, three diagrams, in which the tidal level being reduced to a horizontal line, the abnormal waves alone are shown, for Astoria, San Francisco and San Diego.

I can only refer to the original for the full results deducible from these valuable observations, and repeat here in brief some of their facts:—

"The San Francisco curve presents three sets of waves of short interval: the first begins at 4h. 12m. and ends at 8h. 52m., the interval being 4h. 40m.; the second begins at 9h. 35m. and ends at 13h. 45m., the interval being 4h. 10m.; the beginning of the third is about 13¾h., and its end not distinctly traceable. The crest of the first large wave of the three sets occurred at the respective times of 4h. 42m., 9h. 54m., and 14h. 17m., giving intervals of 5h. 12m., and 5h. 23m."

"The average time of oscillation of one of the first set of waves was 35m., one of the second 31m., and one of the third about the same. The average height of the first set of waves was 0·45 foot on a tide which fell 2 feet; of the second 0·19 foot on a tide which rose 3 feet; and of the third 0·19 foot on a tide which fell about 7 feet; the phenomena occurring on a day when the diurnal inequality was very considerable. The greatest fall of the tide during the occurrence of the first set of waves was 0·70, and the corresponding rise 0·60 foot. In the second set the corresponding quantities were 0·30 and 0·20 foot; in the third *these waves would not have attracted general attraction*." There is a general analogy in the sequence of the waves of the three sets, which seem to mark them as belonging to a recurrence of the same series of phenomena. The series itself looks like the result of several impulses, not of a single one, the heights rapidly increasing to the third wave, then diminishing as if the impulse had ceased, then renewed and then ceased, leaving the oscillation to extinguish itself. If we had a corresponding account of the facts as they occurred at Simoda, the subject would lose the conjectural or rather the incomplete character that belongs to it. Although there is no account of the place of origin of the earthquake, yet its violence on the Japanese coasts and its diminished effects at Peel's Island, as well as the times of arrival of the waves at the Japanese and Pacific American coasts, prove that it must have been beneath the sea, and not far distant from Japan. "Five distinct waves in succession rolled in at Simoda; eight are shown by the San Francisco gauge, of which seven were of considerable height." It seems not improbable, although this does not appear to have occurred to Prof. Bache, that three of the San Francisco waves may have been *reflected waves* only. The highest wave at Simoda was estimated at 30 feet, at Peel's Island 15 feet, at San Francisco 0·65 foot, and at San Diego 0·50 foot.

At San Diego, the gauge shows distinctly the same three series of waves. The first begins at 1h. 22m. later than at San Francisco, correcting for difference of longitude, and ends 52m. later. The interval is 30m. less than at San Francisco, the oscillations being rather shorter than at the latter point. The second begins at 54m. later than at San Francisco and ends 34m. later. The third begins about 54m. later than at San Francisco. The average time of oscillation of the first set is 31m., of the second 29m., being thus respectively 4m. and 2m. shorter than at San Francisco. The average height of the first set of waves was 0·17 foot lower than at San Francisco, and the second as much higher. This fact, taken with the difference in the times of oscillation, induces Prof. Bache to suppose that the difference in the two series was due to interference, which is also suggested by the position of San Diego in reference to the islands separating the Santa Barbara Sound from the ocean.

The difference in the periods of tide on the arrival of the waves at each place would tend to produce discrepancies. The first series at San Diego arrived on a rising tide of 4 feet, while at San Francisco it was upon a falling tide of 2 feet. The second at San Diego arrived at near high water, and was chiefly upon a falling tide of 7 feet, while at San Francisco it was upon a rising tide of 4 feet.

The forms of the waves accord remarkably at both stations.

The tide-gauge at Astoria gives less instructive results, the bar at the entrance of the Columbia River having no doubt broken up and greatly reduced the waves, even if they arrived at the entrance unbroken. The gauge showed a disturbance, but irregular and confused, which was also apparently preceded by (other) unusual oscillations of the water; and Prof. Bache sees reason to think that the San Diego gauge indicates disturbances of the water of an abnormal character *previous* to the great earthquake shock, as well as following it at intervals for several days. The normal time for high and low water does not seem to have been disturbed by the superposition upon the tide-wave of the abnormal or earthquake waves.

From these results Prof. Bache draws the following conclusions as to the rate of translation of the great sea-waves of the earthquake.

The latitudes and longitudes of the stations are:—

	Lat. N. ° ′	Long. W. ° ′	Time. h. m.
San Diego	32 42	117 13	7 49
San Francisco	37 48	122 26	8 10
Simoda	34 40	121 62	14 44

The distance from San Diego to Simoda is therefore 4917 nautical miles, and from San Francisco to Simoda 4527 nautical miles. Assuming the first account of the disturbance at Simoda at 9 A.M. or at 22d. 23h. 44m. Greenwich mean time, and the first great wave 30 minutes afterwards, Prof. Bache proceeds to calculate the rate. There appears to be some typographical errors in the figures, which slightly affect the result which he arrives at, viz. 363 miles per hour, or 6·0 miles per minute. Correcting the erroneous figures, the result would appear to be,—the first disturbance at San Francisco was at 23d. 12h. 22m., or 12h. 38m. after that at Simoda, and the first great wave at 23d. 4h. 42m., giving the same interval (of 30m.). The distance and time therefore give a rate of 368 miles per hour, or 5·966 miles per minute..

Assuming the second account (9h. 15m.), the time of transmission when reduced would be 12h. 13m., and the rate of translation 370 miles per hour, or 6·20 miles per minute.

The San Diego observations, assuming 9h. 0m. as the time of transmission at Simoda, give 13h. 50m., which, when reduced, gives a rate of translation of 355 miles per hour, which is almost identical with the corrected reduction of the San Francisco observations.

Although not directly connected with our subject, it is interesting to state that Prof. Bache deduces from these results a probable mean depth for the Pacific Ocean on the paths traversed by these great sea-waves of from 2100 to 2500 fathoms. (See also Amer. Journ. of Science, vol. xxi. 2 ser. January 1856.)

I deem no apology needed for this lengthened abstract of Prof. Bache's communication, not only because it is, up to the present time, almost the only record of scientific pretensions, of the phenomena of earthquake great sea-waves, but as a model for those who may be engaged in tidal observations upon British or European coasts, of what is needed to make their results connect usefully with the requirements of those occupied in seismical inquiry. The extreme value of self-registering tide-gauges, and the great importance of multiplying these round our own coasts, and upon those of our Mediterranean and antipodal stations, are forcibly shown by the remark of Bache, that but for these instruments, the very occurrence on the North American coast of these sea-waves, which had traversed the whole vast breadth of the Pacific, a distance equal to one-fifth of the earth's circumference, would have actually passed unnoticed. Had there been a competent self-registering tide-gauge at Simoda, we could probably have fixed exactly the spot beneath the ocean at which the earthquake disturbance originated.

There is also a class of doubtful great sea-waves, for the investigation of which such self-registering instruments would afford precious data.

It has been many times observed at various stations round our own British coasts (as well as abroad), that abnormal tides have occurred, or that solitary waves of translation have reached the shore, at abnormal periods, or at uncertain periods of repetition, which could not be confounded with any recognized tidal phenomena.

Such waves have very customarily been referred to earthquakes for their origin of late years; yet very many examples occur in which there has been no account of contemporaneous earthquake, either in the offing at sea, or in any other direction. And the question arises, are such abnormal waves always to be attributed to earthquakes (whether observed or not), or may they possibly be produced by some nodal action or other disturbance far out at sea of waves of other classes, and if so, of what nature?

It will be advantageous to adduce some examples, and the rather, as I am enabled, through the obliging attention of the Commissioners of Public Works in Ireland, to state one of much interest and in some detail, of which no full account has yet appeared.

But first we may notice such an occurrence on the coast near Whitby, Yorkshire, copied from the York 'Herald' of March 8, 1856, for which I am indebted to Mr. William Gray of York.

"York, March 8, 1856.

"Robin Hood's Bay.—On Sunday last, the 2nd instant, at 10 A.M., the tide being then about two-thirds flood, the following phenomenon was observed:—The rocks, which had been bare just previously, were observed to be completely submerged. The water then fell back, and again returned, rushing with considerable force over the rocks and beach. This was repeated two or three times, the water running up a moderately inclined beach the distance of thirty yards.

"A remarkable phenomenon of the tides was observed at Whitby on the 2nd inst. At a quarter to ten o'clock in the morning, being an hour and a quarter before high water, the sea suddenly rushed up Whitby harbour, rising in different places from 18 inches to 3 feet, driving a laden lighter from its moorings, and causing much commotion amongst the small craft. It then receded, but was followed by other and similar waves, so that the tide appeared to ebb and flow six times in the space of little more than an hour. A vessel, which was entering the harbour at the time, was alternately afloat and aground on her passage up, according to the level of the water. About midnight of the same day, the harbour-officers observed a recurrence of the event, and in the first hour of Monday the rush of water appeared to be much more powerful than on Sunday morning. About eleven o'clock on Sunday night, Mr. Tose, the harbour-master, having observed a mark which indicates that the tide was sufficiently high for a vessel then in the roads to enter the harbour, went up the lighthouse and lit the gas-signal. On his return to the pier, he was astonished to find that though the tide ought to have risen higher, it had fallen considerably below the mark. Being afraid the vessel would take the harbour, he was about to extinguish the light, when suddenly the tide rose far above the mark above referred to. At Staithes and Robin Hood's Bay, the phenomenon was also observed. The rushes of water resembled what are known in some rivers as 'bores,' but on a much larger scale. Such phenomena often accompany subterraneous disturbances, and on some occasions they have been terribly destructive. As no earthquake has been felt in these parts recently, it is difficult to account for the phenomenon, and it can scarcely be referred to atmospheric causes. It would be interesting to learn whether a similar occurrence took place on other parts of the coast. Dr. Young, in his 'History of Whitby' (page 792), remarks, 'To volcanic agency may be ascribed this remarkable phenomenon, that on the 17th July, 1761, the tide rose and fell at Whitby four times in an hour.'"

Analogous phenomena have been observed at Pegwell Bay, on the southern coast, during the present year.

The following documents refer to the observations of such waves made upon the coast of Wexford, Ireland, in 1854.

The 'Wexford Independent,' a local journal of the 27th September, 1854, gives the following account:—

"Extraordinary Phenomenon.—We are indebted to Mr. William Campbell, the professional helmet-diver, who has done so much for the improvement of the new pier of Kilmore, by blasting and removing the rocks which impeded its entrance, for the following account of an extraordinary phenomenon, witnessed there on Saturday evening, Sept. 16th, 1854. 'I was' (writes Mr. Campbell) 'in one of our boats seeking after some implements, and not looking seawards, when, on a sudden, I heard a mighty rush of water against the back of the pier, and in a moment it came sweeping round the pier-head, full 3 feet high and abreast. It was within one hour and a half of low water at the time. The inner dock was crowded with the small sailing craft of the place, and quite dry, the tide being more than four hours on ebb. In less than five minutes every boat was afloat, and we had high water. In five minutes more the water ebbed again to the lowest spring-tide. This was repeated seven times in the course of two hours and a half. St. Patrick's Bridge was alternately dry and covered to the extent of a mile, and the sea formed a cascade from end to end of it, the influx appearing to come from the east. At the same time the sea was not by any means rough nor heaving. Standing on the top of the parapet wall of the pier, I could descry two different currents running parallel, and counter currents to these quite visible, the discoloured water running east at a rate of ten or twelve miles an hour, and the intervening water of the original green hue, and stationary. These tide currents were as far out as the shore of the Saltee Islands. I can only compare the current to the opening of a sluice gate. There was no damage done to any of the craft, more than the bursting of a few warps. Had the occurrence taken place at the period of high water, the result would have been the complete overflow of the land in the district, and consequent immense loss. We have often heard old people of that place say that on the Sunday after Lisbon was destroyed by the earthquake of November 1, 1755, the day being remarkably fine, the sea at Kilmore suddenly rose and fell in like manner. This occurrence the other day has been owing, no doubt, to some similar and distant cause.'"

The phenomena alluded to in the above paragraph, from the 'Wexford Independent,' are not unknown on the Waterford coast, and are there popularly termed 'death waves.' It is not very long since two ladies had a narrow escape of being washed out to sea at Dunmore, by a sudden wave, which surprised them whilst seated at a considerable distance above high-water mark on the beach.

Repeated instances are on record of such waves upon the north-east coast of England and upon the south-west coast of Ireland, as well as in many other places (see also Second Report, p. 47–48), and even on the east coast of Africa.

For the following, I am indebted to the Commissioners of Public Works, Ireland:—

"Office of Public Works, October 19, 1854.

"Sir,—I am directed to transmit herewith a copy of a report which the Board have received from James B. Farrell, Esq., County Surveyor of Wexford, respecting an extraordinary tidal phenomenon at Kilmore on the coast of that county on the 16th ultimo. The Board send this report, considering it will be interesting to you, on the subject of earthquakes, to which you are giving your attention.

"To Robert Mallet, Esq." "W. Mooney, *pro Sec.*"

"Wexford, October 10, 1854.—In compliance with the request of the Commissioners, contained in your note of the 22nd ultimo, I forwarded a newspaper in which was an account of the tidal phenomenon at Kilmore.

"Since then I have made inquiries along the coast, tracing from New Ross round by Ballyhack, Arthurstown, Duncannon, Hook Head, Slade, Fethard, Bannow, and on towards Carnsore Point.

"As far as Bannow nothing unusual was observed. The Coast-Guard near there, although one was, as is customary, on the 'look-out' at the time of the occurrence, noted no disturbance. It appears to have been perceived about two miles east of this station, near the point indicated by the line A on the accompanying map, Plate XIII., and seems to have been confined between this and the line B. At 'Ballyhealy,' a little further east, it was not observed.

"From inquiries into the details of the appearance, I learned from Mr. Campbell at Kilmore, that six distinct ridges of water, about 2 or 3 feet high, passed from the west towards the east, very much discoloured and carrying with them large quantities of sea-weed. There was a considerable space between each pair in which the water was of its usual colour, and quite calm, as was the sea generally, there being no wind to disturb it.

"These ridges did not proceed in (broken?) waves, but in continuous lines, and passed on apparently unchecked, while the tide rose and receded on the shore within them, which it did seven times. It is stated that, at the second reflux, the water fell lower than it was ever known by the residents there to fall before.

"It would appear that the ridges maintained their velocity sufficiently to force back the ebb, which flows rapidly round Carnsore Point (nearly three knots an hour) until they passed St. Patrick's Bridge, where the ebb-tide regained its motion westward in the shape of the 'cascade' mentioned by Mr. Campbell in the printed account.

"The disturbance lasted, according to his statement, from 20 minutes past 4 to nearly 7 o'clock P.M.

"On inquiring at the 'Bar of Lough,' I found that at about half-ebb the watchman at the Coast-Guard Station, who was in the watchhouse, which is built on the edge of the sea, felt the floor tremble under his feet, and at the same time the fire-irons and other articles of furniture shook and rattled audibly. He was also startled by 'an extraordinary noise' outside. On going out to ascertain the cause, he found that a large wave was forcing back the ebb. This was repeated three times. The first wave only, however, was accompanied by noise.

"A schooner was lying inside the Lough, at the place marked C, from the master of which, I learned that his vessel was three times swung round, standing alternately to the flood and ebb. He was below, when he had the first intimation of it, and described his being affected with a strange sensation, as if he were getting sick. This I believe is not uncommon in cases of earthquake.

"Mr. Lett, R.N., the Coast-Guard officer here, upon whom I called, made to me a statement confirming what I had collected by inquiry.

"There seems little doubt that the whole thing was caused by a slight shock of earthquake.

"From the information I had at Kilmore from Mr. Campbell, I have laid down lines on the accompanying map, exhibiting the ridges as described by him, and endeavouring to illustrate, by the curved arrows, the action of the ebb-tide upon them. "JAMES B. FARRELL, *Wexford County Surveyor*."

"With reference to the communication addressed to you on the tidal action on Wexford coast, I may mention that since it was sent to you, further information shows that it extended beyond the limits marked by Mr. Farrell, having, by the report of the Coast-Guard, turned Carnsore Point: he has written to the Inspecting Commander of the Coast-Guard, to request he will follow it up, and ascertain how far north the effect was observed.

"Yours, dear Sir, faithfully,

"To Robert Mallet, Esq. "JNO. RADCLIFFE."

21 Oct. 1854."

Referring to Plate XIII., it would appear probable that the primary cotidal line of these waves was about in the direction C C of the heavy dotted line, and that the change of direction, on approaching the shore about B, was due to the conjoint effects, of the meeting ebb tidal-stream round Carnsore Point, of reflection at the Saltees, and of inequality of bottom on reaching the inshore shoal-waters.

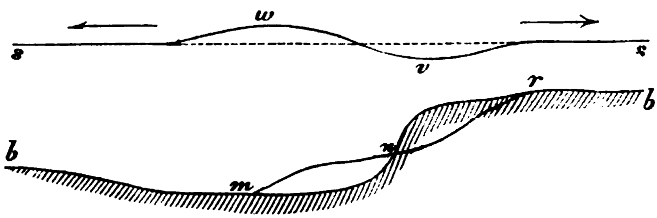
An almost identical train of phenomena occurred at the same point upon the Wexford shore on Sunday, 12th September, 1841. The account is given by Milne, "On British Earthquakes," Edinb. New Philos. Journ. vol. xxxvi. p. 83, and copied from a Wexford newspaper:—"The day was misty and dark, wind S.S.W. to S. Thunder heard at noon; wind lulled, and fog became dense. At Kilmore, ten miles south of Wexford, and directly opposite the Saltee Islands, about noon, a number of short, loud, smothered reports like cannon were heard. The tide had flowed considerably at the time, and the fishing-boats at the pier were all afloat, when, within the space of two or three minutes, the water suddenly receded from the pier, and people walked dry-shod where a little before there had been five to six feet of water. After a few minutes, again the tide began as suddenly to return; and, after resuming its level, continued to rise to high water in the usual way. There was no extraordinary commotion, only an increased surf. The sky cleared after thunder and showers."

The question, however, here chiefly in point is, whence come these waves? what is their origin? The direction of translation, on entering the wide Bay of Ballyteague, here was almost exactly from the south-west, and if transmitted from a considerable distance, the origin of disturbance must have been beneath the deep waters of the Atlantic Ocean, and it is scarcely probable that an earthquake blow sufficiently powerful to have originated waves so large after so long a transmission, should have occurred and *not* have been generally felt in the South of Ireland, where the hard and elastic characters of all the formations are so favourable to the distant transmission of impulses. It is equally difficult to assume, as here operative, a condition which upon coasts of shoal water and encumbered with banks and bars, may unquestionably originate great sea-waves, and which very probably is actually the cause of those of not unfrequent occurrence upon the east and south-east coasts of England.

Almost all great submarine banks are constantly subjected, at the same time, to aggregation by deposition, and to partial degradation, by the sweeping away of material along their bases and flanks, by tidal action, either constant or at certain periods of tide. Deposition takes place by vertical, or more or less inclined precipitation of suspended matter; this form of degradation, by horizontal removal. The conjoint effect is very frequently to *increase the steepness of the angle of slope of the degrading flank of the bank*, matter being constantly added on top and removed from lower down, and with most energy at a level intermediate between the surface-water and bottom.

A time arises, therefore, at which the angle of slope of the bank is increased beyond the limits of repose of the material, whether mud, sand or gravel, or any mixture of these; and then a great under-water slippage takes place, and a mass often of enormous magnitude at once slides from the top and flank of the bank down into deep water, and spreads and levels itself out upon the bottom, to be in its turn swept away and replaced by fresh materials and to give rise to another slippage. Thus, in figs. 9 & 10, if *s*, *s* represent the surface of the sea, *b*, *b* (fig. 9) the sea-bottom in

Fig. 9.



transverse section through the flank of the bank in a plane at right angles to the stream of abrasion; then, at the point where the equilibrium of repose of the mass is lost, the mass *r*, *n* slips and is *suddenly* transported from its original position to *n*, *m*. The effect upon the surface of the sea, is at the same moment to originate a positive and a negative wave, *w* and *v*, whose crests shall more or less approximate to the general line of the flank of the bank; and these will be immediately succeeded by two solitary waves of translation, a greater, *w* (fig. 10), and a less, *v*, whose motions of translation will be opposite.

The magnitude of the wave raised is dependent upon that of the mass of solid material that has suddenly changed its place, upon the depth of water in which the

Fig. 10.

slippage has occurred, upon the rapidity of the transposition, and in a minor degree upon the form and material of the portion of the bank that has slipped. Where the depth of water is very great, its effects at the surface may be quite insensible at the place; but when this low broad flattened wave of only a few inches becomes heaped up on shelving shores or tidal estuaries, it may then become very apparent, and perfectly so to accurate tide gauges. Where the water is comparatively shallow, as it usually is where large and heavy banks occur, there the undulatory effects on the surface, even at the seat of disturbance, will be considerable. We have then a simple mechanism abundantly sufficient to account for the occurrence of some such abnormal tide-waves or great sea-waves as have been noticed; but while thus a *vera causa*, is it *the* cause of any of those phenomena that have been observed, and which do not appear to have been accompanied by earthquakes? This, as well as all the hydrodynamic phenomena of such sea-waves, I would commend to the careful attention of future observers. (See First Report, p. 61.)

Stoppage of Rivers.—Throughout earthquake narratives, nothing is more commonly recorded amongst the secondary phenomena, than sudden derangements of the ordinary and prior regimen of springs, wells, and especially of rivers. Almost all such facts admit of simple explanation; and in the case of rivers, the sudden drying up or stoppage of their streams, has been most usually due to sudden damming up by the fall of *débris* of rocks from precipices, &c. across the river-beds, usually at narrow gorges, where the damming can easily take place, and whence it is, by the posterior rising of the waters, afterwards swept away or gradually removed by floods, &c.; often also on a grander scale, it arises from the occurrence of great landslips (in countries of deep alluvial or other little coherent formation), bulging out into the river-beds, and temporarily shutting them up, and either forcing the streams into new channels, or damming them up until the waters produce a debacle and sweep away the obstacle.

But not a few cases are upon record of sudden stoppages in the ordinary supply of water in river streams, not known to have been connected with any earthquake, or with any sufficient and explainable cause. Perhaps the phenomena cannot be more briefly set forth than by transcribing a notice from 'Chambers's Edinburgh Journal' for Jan. 19, 1839, No. 364. p. 412:—

"Late Stoppage of Rivers in the South of Scotland.—Most of our readers have probably read the accounts which appeared in the newspapers of a simultaneous stoppage of the rivers Teviot, Clyde, and Nith, on the 27th of November last; yet, as many may not have heard of it, and few may have paid to it the attention which it deserves, we are glad to have the opportunity afforded us of bringing the circumstance under the especial notice of our readers. It has, we are glad to find, been taken up, as a subject worthy of scientific investigation; and in this we have been invited to assist, by endeavouring to procure information from any of our readers who may be able to afford it. The phenomenon, it is suspected, is attributable to some agent or cause which had acted over a very extensive range of country, and which, probably, produced similar effects, in many other places besides the banks of the three rivers above specified. We trust that if such effects were perceived by any of our readers, they will be so obliging as accede to the proposal and the request with which we conclude the present notice.

"On the morning of Tuesday, the 27th of November last, about six o'clock, the miller of Maxwellheugh Mill, situated on the Teviot, near its confluence with the Tweed, perceived a great diminution taking place in the water which flowed through his mill-course. At eight o'clock the water altogether ceased to flow. Thinking that the sluice had fallen down, or that the *cauld* [dam] had given way, he went up to the cauld, and found, much to his surprise, that there was hardly any water in the river. There were here and there a few pools, where there were hollows in the channel; but there was no longer a running stream. The channel continued dry for four or five hours—after which the water began gradually to flow, till the waters reached the same level they were at previously. At this place the Teviot is on an average about 50 feet wide, and 2 feet deep.

"The same phenomenon took place in the Nith, in the parish of Durrisdeer, at Enterkinefoot. The channel was so dry, that a person could have walked across without wetting his stockings.

"It was observed also in the Clyde, a little above New Lanark. The extensive cotton-mills at that place were for some hours stopped, in consequence of an entire cessation of the current. Numbers of fish were caught with the hand, and many persons walked across without wetting so much as the soles of their feet.

"The above particulars we have taken from the newspapers, and we do not *vouch* for their perfect accuracy; but we have no reason to doubt it, as the statements have not been contradicted.

"It appears that the same phenomenon has occurred frequently before. In the Teviot, it is known to have occurred at least five times between the years 1748 and 1787. It happened also in the Clyde in the year 1787, and within a few days of its occurrence in the Teviot: and it is remarkable, that, in regard to both of these rivers, the part of the channel where their waters disappeared, turns out to be the very place where they disappeared last month. But there are several other rivers, both in England and in Scotland, where the same phenomenon has been observed within the last half-century.

"We feel satisfied that our readers will share with us an extreme anxiety to discover, if possible, the cause of this singular phenomenon: and we will now explain to them in what way they can be instrumental in assisting in this discovery.

"The first object should be to obtain a minute and accurate account of all the facts apparently connected with the phenomenon, at the places where it was observed. We are happy to learn that steps have been taken for this purpose by persons well-qualified for such an inquiry. But as it is just possible, that even they may not have gathered up all the circumstances calculated to throw light on the subject, our readers in these quarters would do well to note down, ere it fades from their memories, any thing particular which they observed.

"We may now allude to the different theories which have been started to account for the phenomenon, because they will immediately show the importance of gathering together as many facts as possible. It is by facts alone that these theories will be confirmed or refuted.

"Some persons ascribe the phenomenon to a severe frost which occurred on the morning of Nov. 27, and which, it is said, froze up the streamlets and springs that supplied the rivers where the phenomenon was observed. We cannot see how, on any philosophical principles, the effect here stated would follow from such a cause. But, even if it were sufficient to produce it, then the same phenomenon should have occurred in the Tweed, the Jed, and all the rivers where the frost reached. Moreover, it should be observed every winter, and it ought to have been very strikingly observed last winter. Besides, the waters should, after the frost gave way, have risen considerably above their usual level, which, it is said, was not the case.

"We have adverted to these inferences from the theory just mentioned, in order to show how its truth or falsehood may be tested; and many of our readers may be in possession of facts which will supply this test.

"Another theory has been proposed, which, we confess, appears much more probable. It is suggested, that a fissure may have been formed under or across the channels of the above rivers, into which their waters found their way. The current would thus cease to flow in its ordinary channel until the fissure closed, or was filled up by the sediment and water poured into it. The fissure might be either a crack across the country, or a local sinking of the ground. It is well known that earthquakes frequently produce such effects; and there are few years in which, in some parts of Scotland and England, the shock of an earthquake is not felt. When the Clyde stopped in January 1787, a rivulet in the parish of Strathblane, in Stirlingshire, which drove a mill, also disappeared. On the same day, the shock of an earthquake was very sensibly felt in Glasgow and its neighbourhood. Whether or not at either of these places any fissures were observed, into which the streams flowed for a time, we have been unable to learn. That there are fissures, or *slips* (as the geologists call them), which everywhere intersect the crust of the earth, is well known to every collier and miner; and that there are such fissures in that part of the channel of the Clyde, where its waters have repeatedly disappeared (namely, between the uppermost fall and Corra Linn), is extremely probable. It might be thought, however, that, if a crack was produced, sufficient to allow the waters of a large river to escape, it would soon be discovered. But it is quite possible, that, after the lapse of a few hours, the crack might close again, and leave scarcely any external traces of its existence. Still, we cannot help thinking that some traces should be discoverable; and this is just one of the points on which our provincial readers may be able to afford information.

"We shall conclude by suggesting one or two points, to which, if any of our readers would be so obliging as to investigate the subject, their attention may be directed; and we doubt not, other points will occur to themselves:—

"1. Have phenomena, similar to those which occurred in the Teviot, the Clyde, and the Nith, on the 27th of November last, been observed, on the same day, or about the same time, in any other rivers in Great Britain?

"2. If so, at what hour were they first observed, and how long did they continue?

"3. Where is the highest place, in the course of the river, where its waters disappeared?

"4. Was any crack, or fissure, or sinking, or disturbance of the ground, visible at that place?

"5. Was the shock of an earthquake felt, anywhere, about the period above mentioned?

"6. Was there much or any ice on the river, or its tributaries, where the aforesaid phenomenon occurred?

"7. When the water began to flow again, did it rise to a higher level than it had been at previously?

"8. Is there any appearance of a slip, fault, dyke, or trouble in the strata, at or near the place where the waters began to disappear?

"9. Has this phenomenon, or anything similar to it, been observed in former years—and when?

"We may also repeat the queries 3, 4, 5, 6, 7 and 8, with regard to the stoppage of the Teviot, Clyde, and Nith; for on the subjects of those queries with regard to the phenomenon of the 27th of November, we are as yet uninformed."

See also some analogous facts mentioned by Perrey in his memoir "On the Earthquakes of Europe, and adjacent parts of Africa and Asia, from 1801 to 1843" (Comptes Rendus, Sept. 1843, last page but one of the memoir). Most of these phenomena have occurred in the winter and in higher latitudes; and although there are considerable difficulties in the way of the frost theory of accounting for them, and I incline to the view that it will hereafter be found to be the true one, yet there is sufficient to induce the question—Can it be *possible* that partial or local elevations, with or without fractures or earthquake, take place occasionally, and to such an extent as to change the levels of portions of the earth's surface, and for a time derange the flow of rivers, or other such main channels of drainage?

Those who embrace the views of Von Buch and Humboldt, &c., and admit the possibility of *boursoufflé* domes of trachyte, will be prepared to find no difficulty in imagining such comparatively small surfaces elevated and swollen up, by the assumed elastic forces beneath, so as to produce new and extemporaneous water-sheds; and although I cannot join in such views, the subject appears to me worthy of more examination at the hands of Vulcanologists and Seismologists.

Nausea at the moment of shock.—This curious effect of earthquake shock upon human beings, and if accounts are to be credited, also upon some domestic animals, is deserving of more attention than it has yet received.

The fact itself, as respects human beings, admits of no doubt. I have direct testimony of the boys of a large boarding-school being suddenly awakened at night by one of the North American shocks, and the greater number suffering from immediate sense of nausea, amounting to vomiting in many cases. In the late earthquake at Naples (Dec. 1857) many instances were related to me by the sufferers. The question arises, Is the nausea an effect of the sudden disturbance of the nervous system by alarm, &c., or is it due to the movement itself, and analogous to sea-sickness? There are great difficulties in the way of either solution. Those most likely to suffer severely from nervous alarm, do not seem to be those most usually affected. The direct movements are very generally too sudden, sharp, and of too little duration, to admit of the second explanation. The facts, however, require to be more numerous, and to be scientifically collected and classified as soon after the occurrence as possible, and are commended to such physiologists as may be favourably circumstanced for the observation in earthquake regions.

Indirect estimation of the force due to the shock.—In our ignorance of the precise nature of the originating impulse, whether of one or of more than one sort, or of the degree of force at the centre of impulse necessary to transmit a wave, sensibly, to a given distance through the common formations of the earth's crust, any trustworthy observations, of the distance to which the very analogous blow produced by fired mines, or other masses of gunpowder, has been sensibly conveyed, are not to be at present neglected. The 2nd Report gives exact information as to the distances to which such impulses from fired powder, even of a feeble character, may be conveyed through the worst conducting material (sand), and made instrumentally sensible.

I have collected since that period a few occasional notices of the explosions of large masses of gunpowder, and of such facts as may be found, of the magnitude and distance of the impulse conveyed, which I here transcribe for reference. It would be very desirable that officers of engineers entrusted with demolitions, or requiring to explode very large masses of powder, would endeavour to provide for obtaining observations as to the precise radius of the superficial area at which the ground shock became insensible without the aid of instruments, and that such observations were accompanied by a general account of the nature of the geological formation, and of the physical features of the country around.

"The Monster Blast at Furness.—The monster blast of gunpowder at Furness Granite Quarry took place on Wednesday afternoon, with complete success. The charge consisted of no less than three tons of gunpowder, and was deposited in two chambers—one and a half ton in each. The shaft was 60 feet in depth, and the chambers in which the powder was placed were 17 feet long. The charge was ignited by a galvanic battery, and lifted an immense mass of rock, computed to have been between 7000 and 8000 tons. The flame belched out on the seaward side, and was well seen by a large concourse of spectators from Inverary, the watering places of the Clyde, and a party of excursionists from Glasgow, on board the 'Mary Jane.' The report was not loud, but deep and hoarse, and the ground in a very wide circle was strongly agitated."—Glasgow Constitutional, October 5, 1852.

The 'Journal de Turin' of the 29th ult. has, under the head of "latest intelligence," the following paragraph:—"TURIN, 11·45 A.M. Two successive shocks have been felt like those of an earthquake. The powder magazine of Borgo Dora has exploded. The population is hurrying to the scene of disaster. The rappel is being beaten. All the faubourg is on fire. A barrack has fallen down. Two hundred deaths are spoken of."—Saunders's Newsletter, May 1852.

It is quite probable that both in this case and in that of the magazine at Mayence, which subsequently exploded, information might still be obtained as to the weight of powder fired and the extreme distance to which the shock was felt.

Improvement of the Port of Brest.—The 'Moniteur de la Flotte' states that M. Verrier, engineer, charged with the work of clearing away the Rose Rock, which obstructs the entrance of a part of the harbour of Brest, called the Penfield, made an experiment a few days ago, which was perfectly successful. One of the convicts, covered with a diving-dress, descended to the rock at half-tide, and deposited a box full of gunpowder, to which were fitted two gutta-percha tubes, also similarly filled. As soon as the man had come up, a light was applied to the tubes, and shortly after a loud cracking noise was heard, and a large column of water, with fragments of stone and a quantity of sand and mud, were thrown up to the height of 20 feet. The commotion was so great, that the Bastion de la Rose, which stands near, trembled to its foundation. The mass thus moved has been considerable."—Times, April 17th, 1857.

The following is the 'Times' account of one of the explosions at the siege of Sebastopol:—

"Thursday, Aug. 30, 1855.—The whole of the camp was shaken this morning at 1 o'clock by a prodigious explosion, which produced the effects of an earthquake. A deplorable accident had occurred to our gallant allies as they were pursuing their works with accustomed energy. A tumbrel, from which they were discharging powder into one of the magazines near the Mamelon, was struck by a shell from the Russian batteries, which burst as it crashed through the roof of the carriage, and ignited the cartridges within; the flames caught the powder in the magazine, and, with a hideous roar, 14,000 rounds of gunpowder rushed forth in a volcano of fire to the skies, shattering to atoms the magazine, the tumbrels, and all the surrounding works, and whirling from its centre in all directions over the face of the Mamelon and beyond it 150 officers and men. Masses of earth, gabions, stones, fragments of carriages, and heavy shot were hurled far into our works on the left of the French, and wounded several of our men. The light of the explosion was not great, but the roar and shock of the earth were very considerable. The heaviest sleepers awoke and rushed out of their tents. The weight of powder exploded was about seven tons, or 1400 rounds of 10lbs. each."—Times, Sept. 13, 1855.

The following is part of the French account of the expedition against Kertch:—

"May 26th, 1855.—Finally, before evacuating Yenikale, they blew up a powder magazine, containing about 30,000 kilogrammes of powder: the shock was so great, that many houses were destroyed, and vessels anchored ten miles out at sea felt it severely."—'Moniteur' quoted by 'Times,' June 1855.

And the following of the great explosion in the camp before Sebastopol, on the 15th of November 1855:—

"Shortly after 3 o'clock on Thursday afternoon the whole camp, from Inkermann to far beyond Cathcart's Hill, was literally shaken throughout every square foot of its area, by the most tremendous explosion that has ever echoed through these Crimean hills. A greater quantity of gunpowder itself may have been exploded in some of the magazines discharged for the destruction of the buildings and works after the abandonment of the ruined city and fortress; but this is doubtful, and certainly there were never fired at the same time so great a number and variety of deadly and explosive projectiles. The force of the blow from the impelled air, the stunning noise, the flashing of the fire, the suffocating smoke, arrested every reasoning faculty, and took away all sense, save the instinctive impulse to fly from the source of evil. Among the regiments themselves of the light division, whether in tents or huts, a sudden sensation was felt as if of an upheaving of the ground, at the same time that a violent shock was experienced from the concussion of the air. Almost instantly followed the loud report of the explosion; not sounding as if a single charge or magazine had been fired, and without the ringing tone or decided character of a salvo of artillery; but seeming rather as if a number of magazines had been discharged, one after the other, so rapidly, that all the reports were blended into one. As the thunder of the first report subsided, its place was occupied by the sharp cracking sounds of shells bursting high in the air, the rush of fragments falling to the ground, and the loud bangs of shells which had been scattered and were exploding on all sides. Simultaneous with these, almost from the very commencement, was the crushing of wooden huts, splitting of timbers, and noise of falling glass from the broken windows. The tents were violently agitated, and sometimes the cords or poles were snapped asunder. Then followed a continued succession of minor reports, and the roar of flames, and crackling of burning wood, as the fire advanced and increased among the huts and artillery stores of the siege train dépôts. To say that it equalled in violence the combined salvos of a thousand parks of artillery might seem extravagant; and yet the simile would but feebly convey an idea of the volume of thundering sound that shook the earth for miles around, tearing down the most substantial masonry and wooden huts, and levelling tents as by the sweep of some invisible giant-arm. I had seen the explosions on and after the 8th of September, which so many pens have since described; but no half-dozen of them together would have equalled this one, either in force or sound. Over an area of nearly half a mile from the spot of its occurrence, the air was one huge column of powder smoke and cast-up earth, up into and athwart which ignited or exploding shells and rockets ever and anon darted and flashed by hundreds, spreading destruction to nearly everything animate and inanimate, within a radius of more than a thousand yards. Heavy siege guns were wrenched from their carriages and thrown many perches from where they had been standing, whilst the carriages themselves were torn asunder."—London Express, Nov. 29, 1855.

The following notices of the Great Blast at Seaford Cliff are extracted from 'Saunders's Newsletter' of September 15, 1856:—

"The great explosion at Seaford.—There has been a great concourse of visitors in this little town today to witness the operation of 'blasting,' by the explosion of gunpowder, an immense mass of chalk cliff from the heights down upon the beach, there to form a barrier which may check the drifting of the shingle towards Beachy Head and the east. The ground about Seaford for two miles to the west lies low, and there is nothing to protect it from the inroad of the sea at high tides but a narrow beach bank of shingle. This barrier is becoming gradually weaker in consequence of the tendency of the shingle to drift away, and it has become a matter of urgent moment that this should be stayed. Close to Seaford, on its eastern side, rises a noble line of cliff, in some places 300 feet high, and averaging above 200. It was determined to project a huge slice of the cliff on to the beach, with a view thereby to constitute a groin for the purpose of retaining the shingle and preventing its leaving the bay. The operations have been conducted by the Board of Ordnance. The spot selected is not much above half a mile to the east of Seaford. At a height of about 50 feet above high-water-mark there was driven into the cliff, or excavated, a tunnel or gallery 70 feet long, 6 feet high, 5 feet broad, ascending with a slope of 1 in 3. At the inland extremity it turned right and left in the heart of the cliff, above 50 feet one way and above 60 the other, with a more gentle ascent, the two smaller galleries being 4 feet 6 inches high, and 3 feet 6 inches broad, and the three being in the form of a capital T. At the utmost end of each of the side or cross galleries was a chamber, 7 feet cube, lined with wood; and in each chamber a charge of no less than 12,000 lbs. of gunpowder was deposited; making the distance of the centre of the charge 70 feet from the face of the cliff towards the sea, and about 70 feet above high-water mark. The galleries were 'tamped,' that is, stopped up, with bags of sand, and chalk in bags and loose, to within 50 feet of the mouth, both branches being tamped up, and 20 feet down the large gallery. It was not till 12 minutes past 3 o'clock, that suddenly the whole cliff, along a width or frontage of some 120 feet, bent forwards towards the sea, cracked in every direction, crumbled into pieces, and fell upon the beach in front of it, forming a bank down which large portions of the falling mass glided slowly into the sea for several yards like a stream of lava flowing into the water. The whole multitude upon the beach seemed for a few moments paralysed and awe-struck by the strange movement, and the slightly trembling ground; everyone sought to know with a glance that the mass had not force enough to come near him, and that the cliff under which he stood was safe. There was no very loud report; the rumbling noise was probably not heard a mile off, and was perhaps caused by the splitting of the cliff and fall of the fragments. There seemed to be no smoke, but there was a tremendous shower of dust. Those who were in boats a little way out state that they felt a slight shock. It was much stronger on the top of the cliff. Persons standing there felt staggered by the shaking of the ground, and one of the batteries was thrown down by it. In Seaford, too, three quarters of a mile off, glasses upon the table were shaken, and one chimney fell. At Newhaven, a distance of three miles, the shock was sensibly felt. The mass which came down is larger than was expected; it forms an irregular heap, apparently about 300 feet broad, of a height varying from 40 to 100 feet, and running 200 or 250 feet or more seaward, which is considerably beyond low-water mark. It is thought that it comprises nearly 300,000 tons."

These meagre and most imperfect accounts, as respects the object here in view, will however, it may be hoped, direct future attention to more precise observation of the data required.

Report on Observations of Luminous Meteors, 1857–58. *By the* Rev. BADEN POWELL, *M.A., F.R.S., F.R.A.S., F.G.S., Savilian Professor of Geometry in the University of Oxford.*

DURING the year which has elapsed since my last Report to the British Association, I have received a considerable number of communications of meteor observations from various observers, especially, as on so many former occasions, from Mr. E. J. Lowe, as well as from other friends, to whom I am happy to add on this occasion the names of Dr. J. H. Gladstone and Mr. G. J. Symons. The last-named observer is the only one who has recorded any remarkable number as seen at the August period. He has communicated many seen on the 10th of August, 1856, and a still larger number *about* the corresponding time in 1858, few, however, *on* the 10th, but a great number on the 13th. In some parts of England the 10th was cloudy.

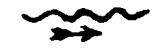
Of the various theories which have been proposed to explain the nature of luminous meteors, some were alluded to in the Report of last year. At the meeting of the British Association at which that Report was presented, a paper was also communicated by Mr. Daniel Vaughan, of Cincinnati, U. S., in which he proposed another hypothesis which seems to have considerable claims on our attention; it has also been given at large in his recent work entitled "Popular Physical Astronomy."

The main principle of this theory is, that the author conceives the luminiferous ether diffused through space, but in obedience to the law of gravitation *condensed* round large bodies, in a more intense degree in proportion to their mass. Hence in our system it is immensely condensed round the sun, but feebly round the planets. When in this state of condensation, it is capable of being acted upon so as to produce the most intense light and heat. As existing round our earth, it can only be sufficiently condensed to produce such effects by the immense local compression arising from the rapid motion of *meteorites*. Hence their luminosity, even when far above the atmosphere; but on entering it, the compression is so great, according to the author's calculation, as to crush them to pieces.

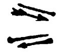
The details of this theory are given in the Appendix (No. 1), by some extracts from the author's work, and also in a letter addressed by him to the author of this Report, with the view to correct some misapprehensions of the theory which have been entertained.

In the Appendix (No. 2) there is given a statement which has appeared in print, of a very singular luminous phenomenon, the nature of which it is difficult to conjecture; but it has the appearance of being the account of a plain matter-of-fact witness, who offers no comment or conjecture. To these, one or two other communications have been added.

List of Meteors observed up to August 1857, by G. J. Symons, M.B.M.S., at Camden Town, London.

Date.	Time.	Mag.	Direction.	Track.	Remarks.
1855.	h m				
Dec. 13	9 10 p.m.	3	SW.–NW.		Very near the horizon.
30	9 0 p.m.	2	NE.–SE.		

Date.	Time.	Mag.	Direction.	Track.	Remarks.
1856.	h m				
March 6	9 48 p.m.	4	SSE.		
June 4	11 5 p.m.	3	ESE.		Very bright though small.
Aug. 2	10 8 p.m.	2	NW.–E.		
3	8 10 p.m.	3	E.–SE.		Several small ones not noted. Moved very slowly. Numerous smaller ones.
7	9 48 p.m.	3	ESE.–E.		
9	10 52 p.m.	2	SE.		Train visible for 10 seconds.
	11 30 30 p.m.	♃	WNW.		Train visible for 30 seconds.
10	0 8 a.m.	3	NE.–NNE.		
	0 13 a.m.	3	NE.–S.		
	0 15 a.m.	3	SE.		
	0 18 a.m.	3	WNW.		
	0 28 50 a.m.	4	E.		
	0 31 a.m.	2	E.–SE.		
	0 35 a.m.	4	ESE.		
	0 37 a.m.	4	SE.		
	1 1 a.m.	2	SE.		
	1 10 a.m.	2	SE.		
	1 12 a.m.	1	SE.		
	1 13 a.m.	4	E.		
	1 18 a.m.	1	SE.		
	1 22 a.m.	1	Close to the Polar Star to S.		Train visible for 30 seconds.
	1 24 a.m.	2	SE.		
	1 29 a.m.	3	SE.		
	9 7 p.m.	♀	N.–S.		See note.
	9 15 p.m.	3	SE.–W.		
	9 18 p.m.	2	NE.		
	9 25 p.m.	4	E.		
	9 28 p.m.	4	S.		
	9 31 p.m.	3	S.–NE.		
	9 54 p.m.	3	E.–S.		
	9 59 p.m.	3	E.–S.		Exactly similar to the one preceding

Date.	Time.	Mag.	Direction.	Track.	Remarks.
1856.	h m				
Aug. 10	10 5 p.m.	3	E.–SE.		
	10 12 p.m.	3	NE.–S.		
Sept. 4	9 54 p.m.	2	NE.–SW.		Across the zenith.
29	11 48 p.m.	2	ESE.		
Oct. 13	10 30 p.m.	1	S.–W.		
	10 35 p.m.	2	N.–S.		Across the zenith.
	11 0 p.m.	3	S.		
	11 7 p.m.	3	S.		
Nov. 6	10 48 p.m.	3	S.		
8	11 28 p.m.	1	NE.–NW.		Brilliant white.
1857. April 6	9 47 30 p.m.	1	NW.		From near α Persei to near ♀. White.
19	1 8 a.m.	1	SSW.		From near Arcturus to near Spica Virginis.
20	9 35 p.m.	3	E.		
	10 10 p.m.	4	SW.		Pale white.
	10 51 p.m.	5	E.–NW.		Across the zenith.
	11 1 p.m.	2	SSE.		
	11 2 p.m.	♂ in opp.	N.–S.		Train visible for 15 seconds.
	11 15 p.m.	1	NE.		
23	9 15 30 p.m.	3	ENE.–E.		
May 11	9 51 50 p.m.	2	SE.–ESE.		Very slow in its movement.
July 14	11 7 p.m.	4	SW.–NE.		Across the zenith, only visible for about 5°.
15	10 46 p.m.	2	Zenith–SSW.		Train visible for 5 secs.; very rapid.
24	11 34 p.m.	...	E.		Like Sirius in colour, but nearly double its apparent brilliancy. See note.
25	10 32 p.m.	3	S.–N.		Across the zenith.
	10 35 p.m.	1	NE.–NW.		
	10 49 p.m.	5	NNW.–S.		Near α Ursæ Minoris.
	10 50 p.m.	2	SE.		
	10 56 p.m.	1	NE.–NNW.		Train lasted 5 seconds.
	10 56 30 p.m.	2	NE.–NNW.		Train lasted 2 seconds.
26	0 4 a.m.	1	SE.–N.		Train lasted 5 seconds.

Date.	Time.	Mag.	Direction.	Track.	Remarks.
1857.	h m				
Aug. 1	0 8 10 a.m.	♃	ESE.		Moved very slowly, varied in lustre.
	0 45 a.m.	2	Zenith–NNE.		
	0 46 a.m.	3	SE.–SSE.		
2	10 2 p.m.	3	NNE.–NNW.		From near β Cassiopeiæ to near Dubbe.
	10 7 p.m.	2	NNE.		From near γ Cassiopeiæ downwards
	10 8 p.m.	2	N.–S.		
	10 20 p.m.	2	N.–W.		Very swift.
28	10 28 p.m.	3	N.		
	10 29 p.m.	4	W.		
	10 44 p.m.	2	E.–SSE.		
	10 49 p.m.	...	ENE.		See note.
	10 55 p.m.	1	E.–SE.		Rapid motion.
	10 59 p.m.	1	SE.		Train of white light.

Additional Notes.

1856.

August 10th, $9^h\ 7^m$ p.m.—This meteor passed N. to S., passing within about 10° of the zenith, leaving a train of light like luminous vapour, which, in spite of the remaining twilight, was visible upwards of a minute.

1857.

July 24th, $11^h\ 34^m$ p.m.—Remarkable for the extraordinary rapidity of its motion.

August 28th, $10^h\ 49^m$ p.m.—This meteor appeared (while I was watching the constellation) between the stars α and γ Cassiopeiæ, of a light blue tint, and apparently double the size of Sirius; as it passed downwards it increased greatly in magnitude, assuming the appearance of an oval disc of a bright violet colour, and leaving a train of brilliant gold-coloured sparks.

List of Meteors from January to September 1858. Observed by G. J. Symons, M.B.M.S., at 27 Queen's Road, Camden Town, London.

Date.	Time.	Mag.	Colour.	Train.	Direction.
1858.	h m				
Jan. 14	9 19 p.m.	> ♃	blue	none	Vertically from a point 3° W. of ♃ towards the horizon.
30	10 42 p.m.	=2× ♃	green	red sparks	From Musca towards ε Andromedæ.
Apr. 17	9 13 p.m.	2	yellow	none	From ρ Ursæ Majoris towards θ Hydræ.
18	9 14 p.m.	3	white	none	From ν Herculis towards α Herculis.
19	1 1 a.m.	1	white	none	From α Coronæ Borealis towards Spica Virginis.

Date.	Time.	Mag.	Colour.	Train.	Direction.
1858.	h m s				
June 1	10 24 30 p.m.	2	white	none	From γ Bootis towards Cor Caroli. (Very slowly.)
	10 51 p.m.	3	white	none	From γ Serpentis towards β Libræ.
2	11 50 p.m.	2	white	none	From Coma Berenices towards δ Virginis.
13	11 23 p.m.	3	white	none	From ε Coronæ Borealis towards Spica Virginis.
16	0 3 a.m.	2	blue	none	From 3° S. of Arcturus towards λ Libræ.
July 28	9 12 20 p.m.	1	white	broad	From ζ Ursæ Majoris towards τ Bootis.
	10 46 p.m.	1	white	none	From μ Lyræ towards α Ophiuchi.
29	0 26 20 a.m.	1	white	slight	From Vega towards ε Herculis. (Swift.)
	0 42 a.m.	1	dull yell.	none	From μ towards ε Ophiuchi. (Very slow.)
	1 1 50 a.m.	1	brill. wh.	slight	From Altair towards τ Ophiuchi. (Swift.)
	1 5 a.m.	1	white	none	From ε Aquilæ towards δ Herculis.
31	0 22 25 a.m.	1	brill. wh.	visible for 5 seconds	From γ Draconis towards α Coronæ Borealis. (Very swift.)
	0 36 a.m.	2	yellow	none	From β Cygni towards ε Ursæ Majoris.
	0 39 a.m.	2	white	none	From α Herculis towards Arcturus.
	0 42 a.m.	3	white	none	From λ Bootis towards Cor Caroli.
	0 49 a.m.	3	white	none	From β Cygni towards ε Ursæ Majoris.
	0 59 20 a.m.	2	white	none	From μ Herculis towards Corona Borealis.
Aug. 1	11 47 p.m.	2	white	none	From η Herculis towards η Ursæ Majoris. (Rather faint.)
	11 49 p.m.	1	white	none	From ρ Draconis towards γ Bootis. (Very bright.)
	11 54 p.m.	2	white	none	From γ Draconis towards η Coronæ Borealis. (Swift.)
2	0 4 a.m.	1	white	none	From ε Herculis towards δ Ophiuchi.
	0 6 a.m.	3	white	none	From β Cygni towards ε Delphini.
	0 6 10 a.m.	1	white	long and brilliant	From Altair towards Scutum Sobienski. (Rapid.)
	0 32 a.m.	2	blue	white	From θ Draconis towards γ Serpentis.
	0 35 a.m.	2	white	none	From γ Ophiuchi towards β Herculis. (Undulating course.) 
3	11 48 p.m.	2	whitish yellow	none	From α Ursæ Majoris towards χ Ursæ Majoris.
	11 57 p.m.	2	,,	slight	From η Cygni towards π Draconis. (Faint.)
4	0 9 12 a.m.	2	white	none	From τ Herculis towards ε Ursæ Majoris.
5	9 41 p.m.	1	yellow	none	From δ Cassiopeiæ towards Capella.
6	9 28 p.m.	1	white	none	From Capella towards Castor.
8	11 1 p.m.	1	white	none	From a point 10° N. of Vega, at an angle of
	11 1 p.m.	4	white	none	about 80° with the horizon, and before it had disappeared (certainly within 2 seconds), a small one crossed it in the opposite direction, but at a similar angle.
	11 7 p.m.	3	white	none	From μ Herculis towards γ Serpentis.
	11 22 p.m.	2	white	none	From Vega towards α Ophiuchi.
	11 24 30 p.m.	1	blue	wh. train	From ε Herculis towards α Herculis.
	11 26 10 p.m.	>1	white	vis. 7 secs.	From ψ Cygni towards γ Ophiuchi.
	11 37 p.m.	2	white	none	From δ Aquilæ towards Corona Borealis. (Faint.)
	11 38 p.m.	1	brill. wh.	none	From θ Draconis towards δ Bootis.
	11 42 30 p.m.	variable.	See Note.		From Cor Caroli towards Coma Berenices.
	11 44 p.m.	1	white	none	From α Draconis towards Arcturus.
	11 54 p.m.	2	white	none	From β Cygni towards α Ophiuchi.
9	11 43 p.m.	2	white	none	From λ Herculis towards β Ophiuchi.
	11 47 p.m.	2	white	none	From ν Draconis towards μ Bootis.
	11 47 10 p.m.	3	white	none	From ν Draconis towards μ Bootis. (Exactly in the same track as the foregoing.)
12	0 5 40 a.m.	2	white	none	From β Cygni towards Taurus Poniatowski.

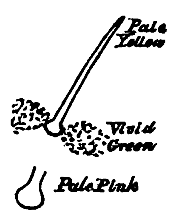
Date.	Time.	Mag.	Colour.	Train.	Direction.
1858.	h m s				
Aug. 12	0 17 30 a.m.	2	white	none	From Vega towards β Ophiuchi.
	0 20 a.m.	3	white	none	From ζ Ursæ Majoris towards Coma Berenices.
	0 21 20 a.m.	2	white	none	From β Herculis towards α Serpentis.
	0 24 30 a.m.	1	white	none	From γ Ophiuchi towards Scutum Sobienski.
	0 33 a.m.	>1	white	none	From π Herculis towards α Herculis.
	0 38 a.m.	2	white	slight	From η Ursæ Majoris towards Arcturus.
	0 41 20 a.m.	2nd and then 1st.	yellow	none	From γ towards ψ, then turned towards π Bootis. (Very slow.) 
	0 49 30 a.m.	1	white	none	From α Draconis towards γ Bootis.
	0 53 10 a.m.	1	white	none	From γ Draconis towards Corona Borealis.
	0 55 35 a.m.	>2×1st	green	none	From β Capricorni towards π Sagittarii.
13	0 30 30 a.m.	2	white	none	From ϵ Cygni towards ϵ Aquilæ.
	0 34 a.m.	3	white	none	From ϵ Herculis towards ν Serpentis.
	0 36 30 a.m.	2	white	none	From μ Lyræ towards β Ophiuchi.
	0 37 40 a.m.	>1	white	slight in the middle of its track, but fading at both ends	From ι Herculis towards ρ Coronæ Borealis.
	0 41 30 a.m.	3	white	none	From γ Lyræ towards γ Ophiuchi.
	0 50 30 a.m.	3	white	none	From ι Herculis towards α Herculis.
	0 55 a.m.	1	blue	slight	From ϵ Cygni towards α Lyræ.
	0 58 30 a.m.	>1	white	none	From 1° S. of Vega towards η Serpentis.
	1 1 10 a.m.	2	white	none	From α Cassiopeiæ towards τ Cygni.
	1 7 30 a.m.	1	white	none	From ϵ Pegasi towards β Aquarii.
	1 7 45 a.m.	2	white	none	From β Aquilæ towards ξ Sagittarii. (Very slow.)
	1 10 30 a.m.	2	white	none	From β Aquilæ towards ξ Sagittarii.
	1 11 30 a.m.	2	white	none	From δ Cygni towards ϵ Cygni.
	1 12 35 a.m.	3	white	none	From β Draconis towards 5° below Vega.
	1 15 30 a.m.	2	white	none	From α Draconis towards Corona Borealis. (Faint.)
	1 18 30 a.m.	= ♀	green	none	From 3° N. of Vega towards ϵ Coronæ Borealis.
	9 55 p.m.	1	white	slight	From κ Cygni towards θ Herculis.
	9 57 p.m.	3	white	none	From σ Cygni towards α Aquilæ.
	10 8 p.m.	3	white	none	From α Persei towards β Andromedæ. (Slow.)
	10 12 p.m.	1	white	none	From η Ursæ Majoris towards Arcturus.
	10 17 p.m.	2	white	none	From γ Lyræ towards α Herculis.
	10 19 p.m.	2	white	none	From Polaris towards δ Aurigæ.
	10 20 p.m.	2	white	none	From τ Herculis towards ϵ Bootis.
	10 22 p.m.	1	white	none	From 3° W. of γ Ursæ Majoris towards Coma Berenices.
	10 24 p.m.	1	white	none	From μ Cassiopeiæ towards Mirach.
	10 45 p.m.	3	white	none	From α Draconis towards Cor Caroli. (Rapid.)
	10 48 p.m.	2	white	none	From θ Draconis towards Corona Borealis.
	10 55 p.m.	1	white	none	From θ Cygni towards ϵ Aquilæ.
	10 57 p.m.	2	white	none	From γ Draconis towards β Herculis.
	10 59 p.m.	3	white	none	From μ Ophiuchi towards ϵ Ophiuchi.
	11 0 p.m.	2	white	none	From between Vega and γ Draconis towards μ Herculis.
	11 1 p.m.	1	white	none	From δ Bootis towards Coma Berenices.
	11 2 p.m.	1	red	vis. for 4s	From γ Ursæ Minoris towards Cor Caroli.
	11 5 p.m.	1	white	none	From θ Cygni towards τ Herculis.
	11 10 p.m.	1	white	none	From γ Ursæ Minoris towards Corona Borealis.
	11 32 p.m.	variable.	See	Note.	From κ Draconis towards Cor Caroli.

Date.	Time.	Mag.	Colour.	Train.	Direction.
1858.	h m				
Aug. 13	11 37 p.m.	4	white	none	From β Ursæ Minoris towards Polaris. Extraordinarily brilliant; I never saw so small an object give so much light.
	11 48 p.m.	2	white	none	From δ Persei towards Pleiades.
14	0 0 5 a.m.	4	white	none	From α Persei towards θ Aurigæ.
	0 0 15 a.m.	1	white	vis. for 3ˢ	From Polaris towards Castor.
	0 7 a.m.	3	white	none	From δ Cassiopeiæ towards δ Persei.
	0 17 10 a.m.	1	white	slight	From γ Persei towards γ Draconis.
	0 19 a.m.	1	white	none	From ρ Ursæ Majoris towards λ Ursæ Majoris.
	0 23 a.m.	1	white	none	From γ Ursæ Minoris towards η Ursæ Majoris.
16	9 20 p.m.	2	white	none	From η Ursæ Majoris towards τ Bootis.
	9 33 p.m.	>1	white	vivid wh.	From α Cygni towards α Aquilæ.
	10 44 p.m.	2	white	vivid wh.	From δ Lyræ towards β Ophiuchi.
	10 47 p.m.	1	white	long	From η Pegasi towards α Pegasi.
	10 51 p.m.	3	white	none	From ϵ Pegasi towards β Lyræ.
17	0 47 a.m.	1	white	none	From Polaris towards α Ophiuchi. No variation in brilliancy throughout its course.
	0 49 a.m.	2	white	none	From α Cygni towards ϵ Aquilæ.

Smaller Mereors were observed on every clear evening between August 1st and 17th, and numbered from 20 to 30 per hour on the 8th, 11th, and 12th.

Additional Notes on the Meteors of August 8th and 13th.

August 8th, $11^h\ 42^m\ 30^s$ p.m.—This meteor (which was the finest of the period), when first seen, appeared the size of a star of the first magnitude; after passing somewhat obliquely for about 5°, and increasing in size, it suddenly threw off a shower of intensely brilliant green sparks, and at the same instant disappeared; just as the sparks were fading away, it reappeared about 3° lower, of a pale pink colour, and much larger than before; after passing about 4° further, it assumed a globular form and instantaneously disappeared. At this time its apparent diameter was between 5′ and 6′. The accompanying sketch is copied from the original in the Observation Book. It must, however, be understood that the appearances were really *in succession*.



August 13th, $11^h\ 32^m$ p.m.—This meteor was remarkable for varying from considerably brighter than a first magnitude star to less than a fourth at intervals of about 7°.

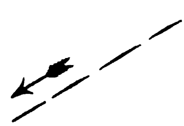


TABLE showing the Number of Meteors passing from and to the respective Constellations.

From	To Ophiuchus.	Bootes.	Hercules.	Corona Borealis.	Ursa Major.	Cor Caroli.	Serpens.	Aquila.	Coma Berenices.	Lyra.	Andromeda.	Auriga.	Virgo.	Sagittarius.	Cygnus.	Draco.	Scutum Sobienski.	Libra.	Gemini.	Hydra.	Delphinus.	Taurus Poniatowski.	Aquarius.	Ursa Minor.	Pleiades.	Perseus.	Pegasus.	Total.
Cygnus	2	...	2	...	2	...	...	5	...	1	...	...	...	...	1	1	...	...	...	...	1	1	...	...	...	...	...	16
Draco	...	6	1	5	...	2	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	16
Hercules	2	2	4	2	2	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	15
Lyra	6	...	3	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	11
Ursa Major	...	4	...	...	2	...	...	...	2	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	9
Ursa Minor	1	...	...	1	1	1	...	...	...	...	...	1	...	...	...	...	...	...	1	...	...	...	...	1	...	...	...	7
Aquila	1	...	1	1	...	...	...	...	...	...	...	...	...	2	...	...	1	...	...	...	...	...	...	...	...	...	...	6
Bootes	...	1	...	...	...	2	...	...	1	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	5
Ophiuchus	2	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	4
Perseus	...	...	...	...	...	...	...	...	...	...	1	1	...	...	...	1	...	...	...	...	...	...	...	...	1	...	...	4
Cassiopeia	...	...	...	...	...	...	...	...	...	...	1	1	...	...	1	...	...	...	...	...	...	...	...	...	...	1	...	4
Pegasus	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	1	3
Corona Borealis	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2
Musca	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Cor Caroli	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Coma Berenices	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Serpens	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	1
Capricornus	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Auriga	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	1
Total	14	13	12	10	7	5	5	5	4	3	3	3	3	3	2	2	2	2	2	1	1	1	1	1	1	1	1	108

Extract of a Letter from Dr. J. H. Gladstone to Professor Powell, dated Aug. 17, 1858.

Several parties have remarked to me the number of falling stars they have seen during the past week. The evening of the 10th was unfortunately cloudy. None of my observations seem comparable with those given in "The Times" of yesterday and today. Mr. Symons seems not to have looked out early enough on the 9th, and thus to have missed the brilliant meteors I saw as I was walking, singularly enough, near his residence.

Meteors observed by Dr. J. H. Gladstone, London, 1858, 21 Tavistock Square.

Date.	Hour.	Apparent Magnitude.	Colour.	Train, &c.	Duration.	Direction or Altitude.	Place.	Observer.
1858. July 20	h m 0 35 a.m.	Far greater than 1st mag.*	Blue	None	More than 1 second	Its course was nearly horizontal, but somewhat downwards; it crossed Bootes, increasing in brightness, and terminated in Canes Venatici as a bright spark almost due N.W., and about 20° above the horizon.	Tavistock Sq., London.	J. H. Gladstone.
21	about 9 p.m.	Clearly visible in twilight.	Red?	....	....	From overhead to W.N.W.......	London	Mr. W. Grubb.
30	10 15 p.m.	Like Jupiter.........	....	....	....	From overhead straight down to due N., passing over a large space.	Tavistock Square	J. H. G.
Aug. 9	9 48 p.m.	=1st mag.*.........	Bluish	Train	Less than 1 second	Nearly horizontal, but somewhat downwards from S.E. to due S. It was about 30° above the horizon when it disappeared.	Camden Town, London.	Id.
	A few secs. afterwards.	=3rd mag.*	Bluish	Train	Less than 1 second	Exactly the same as preceding.	Ibid...............	Id.
	9 53 p.m.	Brighter than Jupiter.	Colourless ...	None	Very rapid	Almost the same as preceding.	Ibid...............	Id.
	9 55 p.m.	Brighter than Jupiter.	Bluish white...	Luminous train lasting 2 secs.	Very rapid	Parallel to preceding, but about 10° nearer the zenith, and from E.S.E. to S.S.E.	Ibid...............	Id.
10	0 12 a.m.	=3rd mag.*	Colourless ...	None	Rapid	From S.S.E. to S., falling at an angle of 45° with horizon, disappearing at altitude of about 15°.	Tavistock Square	Id.
	0 13 a.m.	Flash seen only by	reflexion in ro	om	....	....	Ibid...............	Id.
13	10 55 p.m.	=3rd mag.*	Colourless ...	None	Very rapid	From the zenith, past α Lyræ to W., describing an arc of about 40°.	Near Tavistock Square.	Id.

Older Observations by E. J. Lowe, Esq.,

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1853.	h m				
Oct. 31	8 20	Small, 3rd mag.	Colourless ...	Streamers	Rapid ....
Nov. 1	8 30	2nd size, of 1st mag.*	Yellow	Long train	Slow, duration 1½ sec.
	8 40	Similar..................	Yellow	Train	Rapid ....
	8 50	2nd size Saturn	Blue, increased in brilliancy.	Broke into separate balls..	Duration 2 secs. ...
	9 25	= 1st mag.*...........	Blue............	Train	Duration 1 sec. ...
2	12 30 a.m.	= to Saturn...........	Yellow	Tail	Medium pace ......
	12 31 a.m.	Similar..................	Yellow	Tail	Medium pace ......
7	8 57 p.m.	= 2nd mag.*	Bluish	Stream left	Duration 0·5 sec....
1854.					
Aug. 16	8 25	3 times size of ♃ ...	More orange in colour than ♃.	Without streak, but broke into two balls and disappeared.	Duration 1¼ sec., slow.
	9 14	1st mag.*..............	Orange	....	Slow.................

Observations of Luminous Meteors,

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1857.					
Sept. 16	11 3	= 2nd mag.*	Blue............	Streak	Slow, duration 0·5 sec.
	11 3 2	= 2nd mag.*	Blue............	Streak	Slow, duration 0·5 sec.
29	10 14 30	= 6 times ♃. From the moment it became visible it increased rapidly in size until it was = 6 times diameter of ♃, disappearing suddenly when at its maximum brightness.	Intense blue, very bright.	No streak left after the meteor had vanished. No noise heard.	Duration 1¼ sec.; moved over 11° of sky.
Oct. 8	In the evening.	....	2nd & 3rd mag.	....	....

not inserted in former Catalogues.

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
Perpendic. down from under γ Pegasi.	Aurora Borealis ...	Beeston	E. J. Lowe	Mr. Lowe's MS.
From γ Piscium to η Aquarii...	Many small meteors	Ibid...............	Id..................	Ibid.
Perpendic. down from β Delphini.	....	Ibid...............	Id..................	Ibid.
Moved horizontally towards N., passing near Capella.	....	Ibid...............	Id..................	Ibid.
Perpendic. down passing immediately through Castor.	....	Ibid...............	Id..................	Ibid.
Through α to γ Arietis	....	Ibid...............	Id..................	Ibid.
Perpendic. down through Rigel	....	Ibid...............	Id..................	Ibid.
From α to ι Ursæ Majoris	Aurora Borealis ...	Ibid...............	Id..................	Ibid.
From Æ 14h 54m, decl. 5½° N. to Æ 14h 59m, decl. 7° 40′ S., fading away near ϑ Libræ.	From 8h till 10h, lightning in N.	Ibid...............	Id..................	Ibid.
Across the same path..........	....	Ibid...............	Id..................	Ibid.

by E. J. Lowe, Esq., 1857–58.

Passed through α Pegasi and fell downwards towards the E. at an angle of 45°.	....	Highfield House Observatory.	E. J. Lowe	MS. communication to Prof. Powell.
This started at η Pegasi, and followed the same track as the last meteor.	This meteor seemed to be connected with the last.	Ibid...............	Id..................	Ibid.
Fell perpendicularly down in N., passing 2° E. of the star α Ursæ Majoris and 2° 15′ E. of β Ursæ Majoris, disappearing 3° below and 2° 15′ E. of β Ursæ Majoris.	....	Ibid...............	Id..................	Ibid.
The preceding edge was circular and well-defined, but in every other direction it ended in long streaks of light not unlike streams of Aurora Borealis in form, yet very like electric light in brightness. A lunar halo and faint Aurora Borealis at the time, the temperature 51°·3, wind S., and almost calm ; clouds few cirri overhead, with a white stratus in the valley.				
....	Several meteors ...	Ibid...............	Id..................	Ibid.

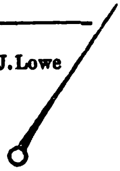
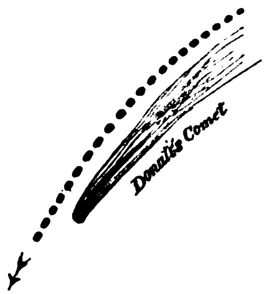
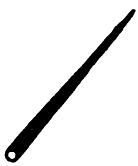
Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1857.	h m				
Nov. 13	7 59	= ♃ in size and brightness.	Greenish	Burst into three balls, and left a streak behind.	Duration 3 secs.; motion slow.
	In evening..	....	....	....	....
23	11 37 45	Twice the size and twice the brightness of ♃.	Yellowish, the streak being a milky-wh.	Leaving a streak behind in its path, which was very brilliant, and which lasted nearly 5 minutes after the meteor itself had vanished.	Rapid; duration of falling through 20° of space only 0·2 sec.
Dec. 7	In evening..	....	....	....	....
	10 59	= 1st mag.*...........	Bluish	....	Rapid ....
	11 10	= 1st mag.*...........	Bluish	....	Rapid ....
19	8 3	= 2nd mag.*	Colourless ...	Leaving a streak...........	Duration 0·3 sec....
1858.					
Feb. 7	6 25	= 2nd mag.*	Colourless ...	Leaving a train	Rapid ....
28	8 11	= in size to Saturn...	Blue...........	Separate sparks left behind	Slow, duration 2 secs.
April 9	In evening..	Small	....	....	....
10	2 0 a.m.	= 2nd mag.*	Colourless until met by a coruscation, and then golden and brighter.	Train	Medium rate ......
May 31	11 30	= ¼th apparent diameter of ☾.	Blue...........	Burst into fragments	Instantly disappeared.
July 21	11 0	= twice size ♃	Colourless ...	No train	Slow................
Sept. 12	8 29 30	= 4 times size of 1st mag.*	Exceedingly brilliant.	Leaving a long train in its track.	Duration 0·8 sec....
	8 30 0	= 4 times size of 1st mag.*	Exceedingly brilliant.	Leaving a lengthy train in its path.	Duration 0·8 sec....

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
Moved from α Pegasi to Jupiter, burst into three balls, which fell perpendicularly down.	....	Highfield House Observatory.	E. J. Lowe	MS. communication to Prof. Powell.
....	Several meteors ...	Ibid................	Id..................	Ibid.
Fell almost perpendicularly down, but inclining slightly W., starting from a position about 3° perpendicularly under Jupiter, and falling 20°.	The colour of the meteor different to that of the streak. Aurora Borealis at the time.	Ibid................	Id..................	Ibid.
....	Many meteors, especially about 11 o'clock.	Ibid................	Id..................	Ibid.
Passed through Ursa Major ...	....	Ibid................	Id..................	Ibid.
Perpendicularly down from β Geminorum.	....	Ibid................	Id..................	Ibid.
Shot horizontally across β Arietis from the direction of Jupiter.	....	Ibid................	Id..................	Ibid.
Fell down through Aries	....	Ibid................	Id..................	Ibid.
In S.S.E., moving downwards towards S. at an angle of 50°, and passing from about halfway between η and ζ Hydræ to near No. 19 in Argo Navis.	The form circular and well-defined. The meteor came from behind a dense cloud, and had the appearance of passing beneath some woolly cumuli; yet probably this was a deception.	Ibid................	Id..................	Ibid.
In all directions, especially near the zenith.	Many small meteors, but their paths not noted, as attention was taken up with a magnificent Aurora Borealis which was occurring at the time. (See April 10th.)	Ibid................	Id..................	Ibid.
Horizontally in N.W. at an elevation of 35°.	This meteor, when it met a coruscation of Aurora Borealis, instantly became *golden* & much brighter.	Ibid................	Id..................	Ibid.
Sky overcast, except an opening in E.S.E. at 10° above horizon. The meteor appeared in this opening.	Night hot, temp. 65°	Ibid................	Id..................	Ibid.
In S. at an altitude of 30° moving towards S.W. horizon, at an angle of 45°.	....	Ibid................	Id..................	Mr. Lowe's MS.
Moved from Vulpecula through γ Aquilæ.	....	Observatory, Beeston.	Id..................	Ibid.
Starting in the zenith and passing down through β Lyræ to α Herculis.	Similar in every respect to the last.	Ibid................	Id..................	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1858. Sept. 12	h m s 8 31 30	= twice that of Mars at time of opposition. Form circular and well-defined.	Exceedingly bright colour, an *intense blue*.	Leaving a slight streak in its track.	Duration 2 secs. ...
30	7 51	= from 2nd to 3rd mag.*, shape elongate.	Colourless ...	Same body seemed to disappear and reappear 21 times.	Tolerably rapid, duration 0·8 sec.
	In evening..	....	....	....	....
Oct. 8	In evening..	....	....	....	....
9	7 13	= 2nd mag.*	Colourless ...	Streak	Very rapid ....
	7 27	= 1st mag.*........	Bluish	Long tail, and leaving a streak in its track.	Motion slow, duration 1·15 sec.

Observations of Luminous Meteors

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1857. Aug. 25	8 30 p.m.	Brilliant ball = ½☽ ...	Orange........	On bursting threw out a shower of fire and disappeared in about 2 secs.	Continued about 3 secs., then burst.
1858. Jan. 10	8 17 p.m.	Brilliant	....	Broke into brilliant reddish fragments.	....
31	10 40 p.m.	Bright meteor = moon and in form of a crescent, as if 5 or 6 days old; became elongated a little, and fell *rotating*; diameter of circle of rotation being about 3 times the diameter of the crescent.	Orange........	Threw off large sparks and disappeared below horizon.	....

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
Path from the Sword-handle of Perseus, moving downwards towards the N., passing 8° above Capella and almost through β Aurigæ, fading away near that star.	Night remarkably clear and cloudless. Day had been very hot, temp. in shade reaching 80°·5.	Observatory, Beeston.	E.J.Lowe 	Mr. Lowe's MS.
Fell perpendicularly down, or rather nearly so, and moving parallel with and 1° W. of the superior edge of Donati's Comet. Had the appearance of moving behind some opake body, as the same shaped object disappeared and reappeared 21 times.	.... 	Highfield House Observatory.	Id.................	Ibid.
....	Many other meteors	Ibid...............	Id.................	Ibid.
....	Many meteors	Ibid...............	Id.................	Ibid.
Moved as if it had crossed Donati's Comet, and was first seen near the nucleus on W. side of Comet.	....	Ibid...............	Id.................	Ibid.
Moved downwards from the direction of the star λ Draconis, and crossing the star χ Ursæ Majoris.		Ibid...............	Id.................	Ibid.

from various Observers.

....	Appeared near......	Southsea, near Portsmouth.	Mr. S. Atkin of Liverpool, Mr. W. J. Hay, Chemist to the Dockyard, and Mr. W. W. Hayes.	MS. communication.
Descended from N. in a curved line towards E.	....	Little Woodhouse near Leeds.	W. Braithwaite, Surgeon.	Manchester Guardian.
In N.W. nearly opposite ☽. 140° (about) distant.	....	Fern's Plat, St. Day, Cornwall.	J. Jeffery.........	Times, Feb. 4, 1858.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1858. Sept. 30	h m 8 45 p.m.	Two meteors near together.	Bright	Bright streak left behind, lasting about 1 sec.	....
May 4	....	Ignited globe	....	Fell down into a farm-yard. Exploded with a loud report; incandescent fragments flew in different directions; one hit a cow.	....
Aug. 8	8 45 p.m.	= ♃	Brilliant white	After meteor had passed, streak remained visible 3 or 4 secs., having a wavy motion, filling up exactly the distance between Polaris and β Ursæ Min.	Instantaneous ......
13	6 39 p.m.	= ½☽. Uniform until the moment of vanishing, when it got sensibly smaller and disappeared as a point.	Very brilliant. At first light blue, then green, and finally a red point. Shape round, no change of form.	Train 12 times the length of the meteor; slightly concave to the horizon; uniform in size; appeared to vanish before the meteor vanished; colour a whitish red; sparks very few, whitish.	Nearly 2½ seconds, rather slower than ordinary meteors, and not quite uniform, appearing to be retarded before vanishing.
Dec. 5	4 45 p.m.	Round and larger than ♃; then divided into two, one going in advance of the other. Both disappeared suddenly.	Bright white...	Train after disappearance..	Almost instantaneous.

APPENDIX.

No. 1.—Extracts from the section on Meteorites, &c., of a work entitled "Popular Physical Astronomy," by Daniel Vaughan. Cincinnati, U.S., 1858 (p. 82 *et seq.*).

After mentioning some of the well-known instances of large meteorites, the author observes that the average of observations shows about one fall annually in the extent of territory including the British Isles and France; or in about $\frac{1}{700}$th of the earth's surface. Chladni calculates that about 700 fall annually on our planet. Their mean velocity appears to be about equal, or even superior to that of the earth in its orbit. [This result seems at variance with that assumed by Mr. Bompas: see last Report.] Solid masses moving through the air experience or produce a pressure nearly proportional to the square of their velocity. This pressure the author calculates, on a mass entering our atmosphere with the velocity of a meteorite, would amount to 80 tons to the square inch, which would suffice to crush it into fragments, especially if descending almost vertically; when more oblique, the resistance and the chance of rupture will be less.

This the author considers a sufficient cause to account for the seeming explosion and noise.

He next adverts to their *luminosity*. Some attribute this to the condensation of the atmosphere by their velocity. But this he considers untenable, as in fact the most luminous meteors are those which move obliquely or even

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
From near γ Andromedæ to near α Lyræ.	....	Osborne Place, Old Trafford, Manchester.	G. V. Vernon, F.R.A.S.	MS. communication.
Smell of sulphur	No hole found, but the straw disturbed and turned up where it fell.	Quainton, 6 miles N.W. of Aylesbury.	....	Communicated by Mrs. Smyth, St John's Lodge, Aylesbury.
From Polaris through β Ursæ Minoris. Disappeared behind house.	....	Stretton, near Ledbury.	Prof. Powell and family.	
When first seen about 25° above horizon S.S.E. Disappeared at 12° above horizon at S.S.W.	....	Temple Gardens, London.	J. Pope Hennesy	MS. communication.
Through the zenith from N.E. to S.W.	....	Near Willesden, Middlesex.	Mrs. Baden Powell.	

horizontally. Of this he gives various striking instances. In fact, all the large, intensely brilliant meteors, move across the sky more or less horizontally, while those which fall near the perpendicular are always small and inconspicuous. The paths of the large and brilliant meteors of Bononia 1670, of 1719 and 1783 in England, were horizontal, while those of Weston, U.S., 1807, of Benares and of L'Aigle, which were less bright, moved in more inclined paths. He observes that the most extraordinary circumstance is the enormous apparent *magnitude* of the luminous mass or ball, as calculated from the ascertained distance. Thus the Weston meteor was 500 feet in diameter, and those of 1719 and 1783 were estimated at half a mile. Yet the quantity of matter known to fall has been but very small in comparison. It has been alleged that only a few fragments were attracted to the earth while the great mass rebounded from the atmosphere, a condition which the author contends is impossible. He is of opinion that the actual solid masses of these bodies are very much smaller, and then adverts to the observations of Professor Lawrence Smith (of which an account was given in the last Report), who has assigned an optical cause for this phenomenon.

The author, however, dissents from that conclusion, and alleges that the effect in the experiments there mentioned, of apparent great enlargement in the discs of luminous bodies seen at a distance, is really due not to any cause analogous to irradiation, or of an ocular kind, as there supposed, but simply to the *reflective* power of the atmosphere, which he considers to be made out by placing near the luminous body any small reflecting substance, and observing at a distance the illumination which it seems thus to spread to some distance around. In a word, he considers the effect in these experiments as due to *illuminated air*, which became visible as distance rendered the glare of the bright central point less overpowering to the eye.

Now this cause he contends cannot produce any effect in the case of meteors above the atmosphere, or even its higher rarefied regions.

"Meteoric stones, fire-balls, and shooting-stars are only luminous at or beyond the boundary of our aërial atmosphere, and cease to be so on their entrance into the denser air . . . . . Of the extraordinary illuminating power of the fluid which burns around shooting-stars, we may be convinced from the vast amount of light which these objects emit, compared with their diminutive size. Although some observers, judging from their luminosity, have ascribed to them a diameter of from 80 to 120 feet, yet from the manner in which so many myriads of them have been lost in the atmosphere during the great meteoric showers of 1799 and 1833, we cannot assign to them a higher rank than hailstones or drops of rain, so far as actual magnitude is concerned." —(p. 95.)

The author is led to his explanation of the luminosity of meteors from the theory of the solar light, which assigns to the external photosphere of his globe the locality of the luminous emanation; and this photosphere he considers to arise simply from the intense condensation upon and near his surface, of the *luminiferous ether*, the same as the resisting medium, diffused through the planetary spaces. He rejects the idea of combustion or chemical changes being the source of the sun's luminosity; as these must in time become exhausted, and the supply of light and heat be consequently interrupted. He alludes to the query of Newton, as to why and how it was that lucid matter should be separated and made to form the sun, while opake matter was distributed among the minor bodies of the system. He then adds,—"But there is no necessity for this unnatural division of matter; since even if the sun were identical in composition with his attendants, yet in consequence of the great superiority of his attraction his surface would necessarily become the focus in which the ether of space must display its luciferous properties."—(p. 98.)

The same law he conceives to apply to the fixed stars; he rejects the idea of the luminosity being due to any mechanical action on the ether dependent on the rotation of these bodies, for then Jupiter and Saturn, by reason of their far greater rotatory velocity, ought to be more self-luminous than the sun. He contends that it is due to "the chemical action which may be expected to take place in the etherial fluid as it condensed around the great sphere." —(p. 101.)

He raises other objections against the theory of Prof. W. Thompson, which was briefly described in a former Report, ascribing the solar light to the impact of innumerable meteors on his surface.

"The (etherial) fluid is so much rarefied in the interplanetary domain, that no chemical changes can take place between its elements, except where it is collected around the largest spheres and compressed by their powerful attraction. In obedience to the law of gravity, which exerts a universal control over all matter, atmospheres of the etherial fluid are collected around the earth and the other large planets, but they are not sufficiently dense for chemical action, except in cases where they receive an additional pressure from meteoric stones sweeping through them with furious rapidity. When these cosmical bodies, on falling to the earth's surface, move in a direction almost horizontal, they take a longer course through the verge of the atmosphere, and the etherial medium is stimulated to chemical activity by the pressure, not only from the meteoric mass itself, but also from the particles of air which it drives in every direction from its passage. As such a chemical action must be attended with a development of heat and light, it is not surprising that meteorites are luminous before reaching the confines of the air, and that their brilliancy is exhibited on a gigantic scale when their paths are almost parallel to the horizon."—(p. 93.)

In further illustration of these views, and to correct some misapprehension which has existed respecting them, it will be desirable here to add an extract of a letter to Prof. Powell from Mr. Daniel Vaughan.

"Cincinnati, Ohio, October 9, 1858.

"I deem it necessary to offer an explanation of the main point of my theory, as the idea I have endeavoured to convey in relation to it has not been correctly understood. I therefore take the liberty to say, that I do not regard meteoric light as due to the presence of a luciferous atmosphere belonging to the meteorite itself; for I cannot believe that any appreciable quantity of ether or of inflammable gas could be confined around such small bodies, or retained by their feeble attractive power after they come in conflict with the air. On the contrary, I have maintained that the light arises from the atmosphere of luciferous ether, which envelopes the earth and which is rendered luminous by the powerful compression of meteorites as they move through it with immense velocities.

"In obedience to the law of gravity, the ether of space must be condensed about all the large planets; but it must undergo the greatest condensation at the surface of the sun. On this vast body the density is sufficiently great to admit an incessant chemical action, giving rise to an unfailing development of heat and light; whereas, in the luciferous envelope of a planet, the same phenomenon cannot be expected, except on the fall of meteoric masses. Of the extent to which the compression of the ether is increased by falling meteorites some idea may be collected from the fact, that a body flying near the earth's surface at the rate of 20 miles a second, would impart to the air a pressure of 150,000 pounds to the square inch, or over ten thousand times the ordinary pressure of the atmosphere. We may therefore conclude that the etherial atmospheres of the several planets must display its illuminating power around the meteoric body, where it is compressed as intensely as it is on the sun's surface.

"A certain degree of compression or density being necessary for chemical action in the ether which maintains solar light, it cannot manifest its light-producing energy in the wide domains of space, nor even on the planets, except in the rare cases of meteoric falls; and it must make the largest spheres above the theatres of its luminous action. My theory, therefore, not only accounts for the fact that the planets are not self-luminous, but also gives intelligence of the vast size of the fixed stars.—DANIEL VAUGHAN."

Mr. Vaughan has given some account of his views to the British Association, 1857; see Sectional Proceedings, p. 42: also in some Essays published in 1853 and 1854, and in an article in the American Journal of Science and Art for May 1855.

No. 2.—The subjoined extraordinary statement is copied from the 'Times' of Dec. 4. It bears the appearance of a simple straightforward account of fact, the nature of which seems difficult to conjecture. It is here inserted simply in the hope of attracting attention, and that in time some light may be thrown upon it by other observations.

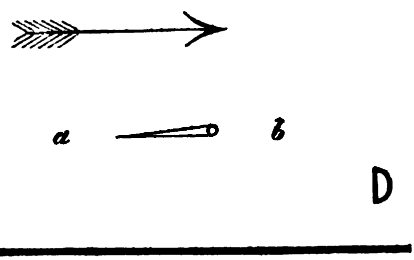
Extract of a letter to the Editor of the Times, Dec. 4, 1858.

"... Last night (Nov. 30), at 15 minutes to 9, it being very dark and raining heavily, I was ascending one of the steep hills in this neighbourhood, when suddenly I was surrounded by a bright and powerful light which passed me a little quicker than the ordinary pace of man's walking, leaving it dark as before. This day I have been informed that the light was seen by the sailors in the harbour, coming in from the sea and passing up the valley like a low cloud....—JABEZ BROWN."

Boscastle, Dec. 1.

No. 3. Oxford, Sept. 13.

At 6½ p.m. a luminous ball was seen in the region of the sky to the east of the moon, and higher than that luminary at the time. It appeared much larger and brighter than any star of the first magnitude. It carried with it



a train or tail like the tail of the comet now visible, and of about the same length. First was seen the ball,—then the tail appeared, in a nearly horizontal line, then ball and tail disappeared. It seemed as though it came out, ran along the sky for a short space, and then entered the sky again.—From a Lady in a letter to Professor Phillips.

No. 4.—The following account of a meteor was communicated by Prof. Stevelly to the British Association, Section A, at the Meeting (1858).

"On Wednesday evening, the 7th of October, 1840, as a number of us were returning from a Lecture on Storms, delivered by Mr. Espy in the rooms of the Natural History and Philosophical Society of Belfast, as we were passing along the east side of College Square, a beautiful meteor appeared for a few seconds, almost due south of us, but a little to the west, and so bright that you could distinctly read by its light. It was then within about 20 minutes to 10 o'clock; the moon was shining, though at the moment obscured by a cloud; and afterwards, when I found that others had seen the same meteor at a distance, we estimated, as accurately as we could, the altitude at which it had been seen, and found it at about 30°. On the night of Friday, the 9th, or two days after, I travelled to Dundalk by the Dublin mail coach, and the guard, Joseph Hill, asked me, had I seen the very brilliant flash of light on Wednesday evening, at about a quarter to ten o'clock. I told him I had, and inquired from him the particulars of where and how he saw it. He informed me of the place, which was about 5½ miles out of Dublin, where the road was very straight, and tending to the north. He had seen it, as he explained, almost overhead, but somewhat to his right hand, and it was so bright for some seconds that the entire place around was lighted up so that a person could distinctly read by it. It had, therefore, been vertically over a place about 75 Irish miles from Belfast, and from these data it is easy to calculate its altitude above the earth, which must have been about 43 miles. A few days afterwards, the same guard, Joseph Hill, sent me the following letter and extract from the 'Warder' Dublin newspaper of Saturday the 10th, which confirms Hill's accuracy, as the correspondent of the 'Warder' must have seen it on the opposite side of the place where it had been vertical from what we did:—

Belfast, 12th October, 1840.

SIR,—I had the pleasure also of seeing this phenomenon the same time as Correspondent. I was about 5½ miles on this side of Dublin when it happened.—Yours, &c., JOSEPH HILL, Mail Guard.

'*Extraordinary Appearance in the Sky.*—(From a Correspondent.)—About a quarter before ten o'clock on Wednesday, at an immense altitude, a white ball of fire appeared in the north-eastern part of the sky for a moment, and shot downwards, illuminating the whole heavens, and causing an extraordinary sensation in those who witnessed it before its descent. The ball was tinged with a beautiful violet blue.'—From the 'Warder' of Saturday, October 10, 1840."

On some Points in the Anatomy of the Araneidea, *or true Spiders, especially on the internal structure of their Spinning Organs.* *By* R. H. MEADE, *F.R.C.S.*

[A Communication ordered to be printed entire among the Reports.]

IT is not my intention in the present communication to enter generally into the anatomy of spiders, but to confine myself to an account of the arrangement and structure of the parts contained in the abdomen; and more especially to describe the glandular organs by which the silk forming their webs, is secreted.

I was led to undertake this investigation by the hope that an accurate examination into the minute anatomical structure of the spinning organs might clear up some important differences of opinion as to their functions. Martin Lister, Cuvier and others, contend that spiders have the power of forcibly ejecting the fluid which forms the silk from their spinnerets; and are thus able to propel a thread to a considerable distance, and in any direction. Both the above-named naturalists state that they have distinctly seen them shoot out their webs, but Mr. Blackwall (the greatest living authority on Arachnology) denies that they have any such power, and says that the tenacious fluid is simply emitted from the extremity of the abdomen by pressing it against some fixed point, and then drawn out into a thread by a current of air, and wafted to some neighbouring object to which it adheres, or left floating in the atmosphere. Should my researches fail to clear up this interesting question, they may tend to elucidate some other curious points connected with the functions of the spinning organs,—such as the power which spiders have of forming different kinds of threads from the same spinnerets, some of which are adhesive, while others have no viscidity, but simply form a framework to support the others.

I met with considerable difficulties in the course of my investigations, had to make numerous dissections, and at last was unable to arrive at satisfactory conclusions on many points; for the organs are so small and delicate, and become so brittle when the spiders have been preserved any time in spirits, that it is not easy to separate them. My plan has been to dissect carefully in water or spirit, under a simple lens, and then to submit each portion separately to the action of a compound microscope.

The abdomen of spiders is covered by a tough integument, consisting of three layers: the external one is a thin transparent horny membrane, nearly colourless, but more or less densely covered with coloured hairs; beneath this lies a soft layer of pigmentary matter, upon which the peculiar colour of the body depends; for it may be observed, that, when the hairs with which the body of a spider is clothed are rubbed off, the integument beneath is usually of a dark tint. The third or inner layer consists of an expanded network of muscular fibres, which are irregularly interlaced, and which must enable the spider forcibly to compress the abdomen. The muscles forming this layer are very faintly, if at all, marked with transverse striæ (see Plate XVI. fig. 1).

At the apex of the abdomen, on the under side, is the anal tubercle, partly concealing the opening of the intestinal canal; and immediately in front of it are seated the spinnerets, a group of projecting processes or mammulæ; mostly articulated, and moveable in all directions. Their number is generally six, but sometimes they are reduced to four, and, as Mr. Blackwall discovered, they amount to eight in one family. They are placed in pairs, closely grouped together. When six in number, the two anterior and two posterior are much larger than the two intermediate ones, which in a state of repose are hidden beneath the others (see Plate XVI. figs. 2 and 3). The posterior spinnerets are often triarticulate, and have the terminal joints much prolonged and very hairy, when they have been called anal palpi, and supposed not to take any part in the construction of the webs; Mr. Blackwell, however, demonstrated their true character, showing that they are provided with moveable papillæ for the transmission of the silk, like the others. The external anatomy of the spinnerets has been so fully described by Mr. Blackwall *, who has shown the number and arrangement of these papillæ, which vary greatly in different species and on the different spinnerets, that I need not dwell further upon them. In Plate XVI. fig. 6, I have represented some of them, which are like hollow bristles with dilated bases.

In the spiders belonging to the family of the *Ciniflonidæ*, Blk. (the type of which is the common *Ciniflo* (*Clubiona*) *atrox*), there is a fourth pair of spinnerets. They are short, compressed, and inarticulate, and different in appearance from all the others. They are seated at the base, and in front of the ordinary anterior pair, and have each on the surface an oval flattened space perforated with an immense number of exceedingly minute pores, which are the orifices of the spinning tubes (see Plate XVI. fig. 5).

The spinnerets are connected with the surrounding integument by means of diverging bands of muscular fibres (Plate XVI. fig. 3), which enable them to move in different directions; these muscles are placed immediately beneath the skin, and their expanded extremities are inserted into it so that they are separated with it, unless dissected very carefully.

In the interior of the abdomen, nearer to the base than the apex, and in female specimens opposite the opening of the oviduct, is a fixed spot, probably tendinous in character, from which muscular bands radiate in various directions, keeping the different abdominal organs in their places. Some of these bands are inserted into the integument on both the ventral and dorsal surfaces of the body; others run backwards in straight parallel bundles, and pass into the interior of the different spinning mammulæ. The last-mentioned fibres are strongly striated (Plate XVI. fig. 7), while those passing from the same point to the skin, like the muscles fixing the margins of the spinnerets to the integument, are almost destitute of striæ. When the abdo-

* Report on the *Araneidea*, British Association for 1844.

men is opened, a large quantity of adipose matter comes into view, which supports and separates the different organs. In recent specimens this tissue is formed into lobules, which are again connected by fine cellular tissue into larger lobes (see Plate XVI. fig. 8); when, however, spiders have been kept for some time in spirit, the connecting tissue disappears, the lobules break up, and a mere unconnected granular mass remains. This reservoir of fat is a storehouse of nutriment, which enables spiders to bear very long abstinence; and when they have been deprived of food for a long while, the abdomen becomes small and shriveled. This adipose matter was described by Cuvier and others as the liver. The chief organs which the abdomen contains are the ovaries (in the female), the intestinal canal, and the glands for the secretion of the silk. The ovaries, which shortly before the deposition of the eggs occupy a large portion of the cavity, are seated in the central and posterior part; the intestinal tube runs through it, in nearly a straight direction, from the base to the apex; and the sacs and tubes which elaborate the material for forming the webs, are placed in the lower, lateral, and anterior parts. I shall confine myself to the anatomy of the last-named structures, merely noticing with regard to one of the others, that I have generally observed the lower part of the intestinal canal to be filled with a whitish turbid excrementitious fluid, sometimes mixed with black particles*. After having been some time in spirit, this fluid is converted into a whitish substance of the consistence of mortar.

The silk-glands, with their excretory tubes, which I shall now proceed to describe in detail, are very numerous, and of very beautiful construction. They essentially consist of a number of hollow cavities or sacs, of different sizes and shapes, each of which is furnished with a distinct duct. None of them or their ducts have any communication with each other, but terminate separately at the extremities of the spinnerets. The nature and construction of the glands are essentially similar in all the species of British and foreign spiders that I have dissected, though they differ greatly in form and number. As might be expected, they are most highly developed in the web-spinning species; while in those that hunt for their prey, as the Lycosæ, they are few and small in comparison, with the exception of those species which are aëronautic in their young state. They appear to be similar in the males and females.

When the integument of the lower and front part of the abdomen is removed, together with a thin layer of fat, and the muscles which move the spinnerets, a large bunch of minute vesicles (just visible to the naked eye in a large spider, such as *Epëira diadema*) is brought into view; these, examined by the microscope, are found to be small transparent oval sacs about 200th of an inch in diameter in *Ep. diadema*, with fine and exceedingly elastic ducts, which proceed in bundles into the anterior and posterior pairs of spinnerets; few, if any, terminating in the intermediate pair. When accurately examined, these small glands are found to be of two kinds; the most superficial, which are fewer in number than the others in *Ep. diadema*, are spindle-shaped, and imbedded in oval capsules of an opake finely granular substance, which is brittle and easily rubbed off, when pressed between two pieces of glass. I have endeavoured to represent these in Plate XVI. fig. 10 *a*, and fig. 11. The other cells, which are more deeply seated, are exceedingly numerous in some species; they are nearly transparent, but when examined by a good glass look as if they were embossed, or covered with little eleva-

* Mr. Blackwall noticed that the excrement of spiders often contained these black particles, which had previously been described as calculi.

tions. I think this is an optical illusion, and that the appearance is due to the interior being furnished with numerous cavities or hollows (Plate XVI. fig. 10 *b*, and fig. 12).

In *Ciniflo atrox* and *C. ferox*, and probably in the other species of the same family, there are a number of very minute sacs, imbedded in granular opake matter, which are not more than a fourth of the size of those which I have before described; they are of a round or pear-like shape, with the appearance of a nucleus in the interior, and are furnished with exceedingly minute ducts. I found them close to the spinarets, beneath the skin, and their ducts probably proceed to the minute orifices on the extremity of the extra pair of spinnerets; but owing to their extreme delicacy, I could not succeed in tracing them there (Plate XVI. fig. 13).

In the middle and even upper parts of the abdomen are a number of tubular or bag-shaped cavities, which vary much in shape, number, size, and structure in different species; some are hard and cartilaginous in consistence, with transparent walls; these present no appearance of fibres under the microscope, but when forcibly compressed, crack and break into irregular fragments. Their ducts seem similar in structure to the body of the sac, being hard and brittle. In *Epëira diadema* and *Ep. quadrata* these glands are of a large size; in the former species there are six of them, three being on each side; they are somewhat cylindrical in shape, and very much convoluted (see Plate XVII. fig. 1 *a*). I succeeded in tracing one of their ducts into each of the six ordinary spinnerets. In *Agelena labyrinthica* they are represented by several oval-shaped sacs, of moderate size (see Plate XVII. fig. 1 *c*), quite transparent, and so firm in consistence, that they feel like solid bodies when taken between the fingers.

We now come to a series of membranous sacs, of various shapes and sizes, some being large and vermiform, others club-shaped, while others are dilated in the middle and furnished with branched cæca. All these different forms do not occur in the same individual, but some in one species and some in another; they all appear, however, to resemble each other more or less in structure. When any of the larger varieties are minutely examined, their walls appear thickened and fibrous. Their inner surface is studded with minute cavities or hollows, giving it somewhat the appearance of the interior of a piece of human intestine, with its *valvulæ conniventes*; thus affording an increased surface for secretion. When carefully removed from the surrounding textures, they all appear coated externally by soft granular matter. I think it probable that the blood or nutritive fluid which supplies the materials for secretion circulates in this coat, which must therefore be considered as the cortical part of the gland. These sacs are well seen in *Agelena labyrinthica*, where they are met with of a large tubular or clavate shape. I have figured three (Plate XVII. fig. 7), the ducts of which I found terminating in one of the elongated posterior spinners; fully confirming Mr. Blackwall's opinion as to the true nature of these anal palpi, as they have been called. In *Ciniflo ferox* I noticed two large branched sacs of a very peculiar form (see Plate XVII. fig. 6).

One of the most interesting parts of the structure of these membranous sacs is the formation of their excretory ducts. A transparent and highly extensible tube is encircled by a fibrous or muscular coat, which loosely surrounds it, and seems to be a continuation of the outer coat of the sac itself. When the ducts are stretched, which they unavoidably are in their removal from the body, this breaks up into circular rings and becomes loose from the tube within, which is exceedingly extensible, and stretches out so as to become much less in diameter than the outer coat. This structure may be very plainly seen in *Agelena labyrinthica* and *Ciniflo ferox*, but is still more distinct in some large foreign spiders. I have figured a sac and tube taken from a large species of *Olios*, which I had an opportunity of dissecting through the kindness of Dr. Gray of the British Museum (Plate XVII. fig. 5). The ducts from these glands seem principally to terminate in the posterior and intermediate spinnerets, but I have traced some of them (especially in *Ciniflo ferox*) into the anterior pair. When dissecting a large specimen of *Mygale*, I found that the fine ducts proceeding from the numerous small oval glands in the vicinity of the spinnerets had all the same structure as those I have described (Plate XVI. fig. 12 *b*). I have noticed that some of the larger ducts proceed parallel with, and are partly imbedded in, the fibres of the muscular bands which extend into the interior of the spinnerets (see Plate XVII. fig. 8).

I shall now endeavour to draw a few physiological inferences from the facts I have imperfectly related. Every papilla or spinning tube is furnished with a separate duct, so that each thread which a spider spins is secreted by a distinct gland having no communication with its neighbours; and there can be no doubt that different varieties of silk are secreted by the different kinds of glands; but it is exceedingly difficult to demonstrate the fact, as no direct experiments can well be made in proof of it. Treviranus says that he thinks the small glands near the spinnerets of *Ciniflo atrox*, the existence of which he ascertained (I do not mean the minute ones connected with the additional spinnerets), contain a different kind of fluid from that in the large sacs; but they are so small, that I do not think it possible to determine the nature of their contents except by the colour, and that must be influenced by the structure of the walls of the sacs or glands.

We have seen that the secreting glands are of very different sizes and kinds; the orifices in the spinnerets, and the spinnerets themselves, are also different; and reasoning upon these facts, and upon some points which may be considered as proved, in the economy of the spinning organs, I think we may be justified in drawing certain conclusions, or rather offering suggestions as to their uses.

I have said that in *Ciniflo atrox* and allied species there is a distinct pair of supplementary spinnerets, furnished with a fine sieve-like surface, for the emission of a number of exceedingly delicate threads; there are also a number of very small and peculiar looking cells, apparently connected with these spinners; now Mr. Blackwall has distinctly shown that these spinnerets perform a peculiar function, spinning exceedingly fine lines of pale blue silk, which is woven into a flocculus, as he calls it, by a most beautiful comb or calamistrum connected with the hind legs*, which flocculus performs a peculiar office in the webs of this spider. In this case there are a distinct set of glands, connected exclusively with a distinct pair of spinnerets, so that it is very easy to determine their functions; the other glands, however, have not peculiar spinnerets to themselves; therefore there must be a greater uncertainty in hazarding opinions as to their uses.

By far the most numerous, and most constant in size and shape, of the spinning glands in spiders generally, are the small ones seated near the spinnerets; these probably secrete the finer threads which form the more delicate textures of their webs, construct the cocoons in which they enclose their eggs, and the retreats in which some of the species conceal themselves.

I remarked that the hard cartilaginous sacs were peculiarly large and numerous in the geometric spiders, as *Epëira diadema*. I would suggest that they secrete the adhesive threads, which are spirally fixed upon the

* Researches in Zoology, p. 273.

framework of elastic filaments first constructed. The common house spider (*Tegenaria civilis*) is said to form no adhesive lines, and I have been unable to find any of the cartilaginous glands in its abdomen.

We now come to the consideration of the various shaped membranous sacs, the ducts of which are much larger than in the cartilaginous kind, and, as I have shown, are furnished with a fibrous coat arranged in distinct rings. I have no doubt that these sacs form the fluid which constructs all the strong non-adhesive threads spun by spiders, and also the floating lines or gossamer of the aëronautic species. In support of the latter assertion, I have found that two of the most common among the aërial spiders, viz. *Lycosa saccata* and *Thomisus cristatus*, contain these sacs in great size and number; whereas they are erratic species spinning no regular webs, and therefore having no other apparent use for them. In most other species of Lycosæ the spinning organs are in a very rudimentary state.

I have now arrived at the most interesting, but most difficult part of my task, viz. the question whether there is anything in the structure of the silk-forming organs that will decide the question as to the power of spiders to eject their threads to a distance. Looking at the strong fibrous coat on the ducts of the membranous sacs, and the fibrous tissue surrounding the glands themselves, I think that they must possess a powerful contractile power, which may also be increased by the muscular coat of the integument enabling the spider to compress its abdomen: may not the striated bands of muscular fibres, which run in a parallel direction down the middle of the abdomen quite into the interior of the spinnerets, and surround the termination of the ducts, also assist in this object? They are not attached to the tegumentary coverings of the spinnerets like the other muscles, and cannot therefore be for the purpose of moving these processes; their action must be to draw the spinnerets inwards. On examination of the pectoral muscles which connect the legs with the cephalothorax, and which possess great power, to enable the spider to perform its various active movements, I found that they presented exactly the same microscopic appearances as the deep abdominal muscles, being very strongly striated; I therefore conclude that the latter perform some very active functions.

In adopting the conclusion that spiders have the power of forcibly propelling the silky fluid from their spinners, I know that I am running counter to the convictions of Mr. Blackwall, for whose opinion on all points connected with Arachnology I have the greatest veneration. That patient and acute observer based his views upon the result of many carefully conducted experiments; he found that spiders, when placed upon an upright stick which had its base fixed in water, could not escape when they were covered by a glass shade, so as to prevent any movement of the air; but when left uncovered, in the ordinary atmosphere of a room, they emitted a little fluid from their spinnerets, which was drawn out into a thread by the slightest current of air, and soon became attached to some neighbouring object. I think it very probable that a current of air may thus draw out these almost imponderable lines in some cases, but I consider that we cannot thus account for the formation of their threads under all circumstances and in all places. We have also the testimony of Cuvier and others, that spiders sometimes eject their threads simultaneously in opposite directions. Cuvier has seen this feat performed by a *Thomisus**, and Kirby and Spence quote an observation made by an anonymous author, who says he saw a small spider shoot out obliquely in opposite directions small threads, which attached themselves

* Règne Animal.

in the still air of a room, without any influence of the wind, to the objects towards which they were directed *.

Spiders are exceedingly sagacious, and vary the expedients which they adopt to escape from confinement or to reach a neighbouring object. I was much interested lately in observing one (*Epëira inclinata*) shift its position. It was on a horizontal piece of wood, and wished to reach another piece placed about a foot beneath it, and at a short distance from it laterally. It suddenly dropped, spinning a thread as it fell, which of course it had first fixed to the wood above. When it had fallen to a little below the level of the object which it wished to reach, it stopped itself by catching the line with one of its feet, and remained suspended in the air by the thread. It now made several violent jerking movements, and thus acquired a swinging motion, which it managed to increase until it brought itself into contact with the neighbouring object: as soon as this was effected, it clambered on to it, and walked leisurely away.

Explanation of the Plates.

Plate XVI.

Fig. 1. Portion of the muscular layer of integument.
Fig. 2. Spinnerets from a large species of *Olios*.
Fig. 3. Spinnerets of *Epëira diadema*, with motor muscles.
Fig. 4. Portion of one of the same muscles, greatly magnified, showing its attachment to the skin.
Fig. 5. Spinnerets of *Ciniflo ferox*:—*a*. Extra spinnerets, which form the flocculus; *b*. Cribriform surface on the same.
Fig. 6. *a*. Papillæ or spinning tubes on a portion of a spinneret; *b*. Highly magnified view of one papilla.
Fig. 7. Striated muscle from the interior of abdomen:—*a*. Bundle of fibres; *b*. One fibre, highly magnified.
Fig. 8. Fat lobules.
Fig. 9. Interior of the abdomen of *Epëira diadema*, showing the silk-glands *in situ*.
Fig. 10. One of the spinnerets of *Epëira diadema*, with portions of striated muscle, and some of the small oval and fusiform glands attached.
Fig. 11. Two of the fusiform glands, with their granular capsules highly magnified.
Fig. 12. *a*. Oval gland, from *Epëira diadema*, showing its embossed appearance; *b*, Ditto, from a large species of *Mygale*, showing its duct with a fibrous covering.
Fig. 13. Minute glands near the supplementary spinners in *Ciniflo atrox*; two ordinary glands appear with them.

Plate XVII.

Fig. 1. Cartilaginous or hard silk-glands:—*a* and *b*. Two varieties from *Epëira diadema*; *c*. Variety from *Agelena labyrinthica*.
Fig. 2. Membranous sac and duct from *Agelena labyrinthica*.
Fig. 3. A portion of the body of the same, highly magnified.
Fig. 4. A portion of the duct of the same, highly magnified.
Fig. 5. Large sac from a species of *Olios*:—*a*. A portion of the duct of the same, showing the fibrous coat.
Fig. 6. Peculiar shaped sac, with branched cæca, from *Ciniflo atrox*.

* Introduction to Entomology, 3rd edit. vol. i. p. 418.

Fig. 7. One of the posterior triarticulate spinners from *Agelena labyrinthica*, with spinning glands attached.

Fig. 8. Portions of duct, from spinning glands imbedded in muscle, just as they are entering one of the spinnerets.

The Patent Laws.—Report of the Committee of the British Association. Presented by W. Fairbairn, *F.R.S.*

The subject of the Patent Laws has frequently occupied the attention of meetings of the British Association, and committees have from time to time been appointed for the purpose of considering how those laws might be rendered more efficient for the objects with which they are maintained. The Rev. Vernon Harcourt, in the inaugural address at the first meeting of the Association, held at York (September 1831), in which he expounded the objects and plan of the Association, referred to those laws as an instance in which fiscal regulations interfered with the progress of practical science, and as failing to give protection to property in scientific invention to the same extent as protection is given to every other species of property; and he suggested a revision of those laws as one of the subjects to which a scientific association might be justly expected to call public attention; and Sir David Brewster, and others, have on several occasions brought the subject before meetings of the Association.

By the Patent Law Amendment Act, passed in the session of 1852, the rights of the inventor to property in the offspring of his brain, and in the creations of his intellect when embodied in products of national industry, were fully recognized; provisional protection to that property was secured to such inventor from the date of his application for a patent; one proceeding was substituted, and one patent issued, extending to the whole of the United Kingdom, instead of three proceedings and three patents separate and distinct for each of the three countries, England, Scotland and Ireland; property was created and protection obtained for six months by a payment of £5; for three years by a payment of £25; and for the further terms of four and seven years, by additional payments of £50 and £100 respectively, instead of by the payment of upwards of £300 in the first instance, under circumstances of such uncertainty as threw discredit on the whole system; the specifications of all patents are to be printed and published, and sold at extremely low prices; a benefit to the public as well as the inventor, which it would be difficult to estimate too highly; and, lastly, provision was made for the regulation of matters relating to patents by commissioners furnished with ample powers for the purpose.

This Act came into operation on the 1st of October, 1852, and the experience of the first two years showed that the payments by inventors upon the above scale of charges would be at the rate of more than £50,000 per annum, without including the further or additional payments for the maintenance of the patents for the further terms of four and seven years, after the expiration of the first three or seven years respectively.

At the meeting of the British Association in Liverpool, September 1854, a committee, presided over by the Earl of Harrowby, was appointed "for the purpose of taking such steps as may be necessary to render the patent system and the funds derived from inventors more efficient and available for the reward of meritorious inventors and the advancement of practical science." This committee communicated with the Earl Granville and Lord Brougham, to whose exertions and watchful care the passage of the measure of 1852 was mainly due; and made a report to the meeting of the British Association, held in Glasgow in the following year, when the subject of the tax on inventors and the appropriation of the funds so levied was fully discussed; and another committee, consisting of His Grace the Duke of Argyll, the Earl of Harrowby, Colonel Sabine, the Master of the Mint (Prof. Graham), Mr. Fairbairn and Mr. Webster, were appointed with similar powers. The Glasgow Committee addressed a memorial to the Lord Chancellor (Lord Cranworth), calling attention to the proceedings which had taken place at the various meetings of the British Association, to the numerous questions of administration and legislation then adverted to, or which might be expected to arise, and suggesting that Her Majesty should be advised, in accordance with the provisions of the Patent Law Amendment Act, 1852, to appoint others than the official commissioners, and to make the working of that Act the subject of immediate inquiry.

At the meeting of the British Association, held at Cheltenham in 1856, a committee, consisting of the Earl of Harrowby, Lord Stanley, M.P., Mr. Fairbairn, Prof. Graham, the Master of the Mint, Mr. James Heywood, Mr. Commissioner Hill, General Sabine, and Mr. Webster, were appointed with like powers; the Earl of Harrowby and Mr. James Heywood communicated personally with the Lord Chancellor; the Lord Stanley took a warm interest in the subject, embodying his views on the necessary alterations in a published pamphlet; but up to this time the objects in view have not been attained, and it will be for this meeting of the British Association to consider what further steps should be taken.

The printing and publication of the specifications has led to results which were hardly anticipated, as to which the following extract from a Report of the Commissioners of Patents in 1856, will be read with interest:—

"The Commissioners of Patents have presented complete copies of all their publications to such of the government officers and seats of learning as have applied for them, and to the principal towns in the United Kingdom, on condition of their being daily open to the inspection of the public free of charge. In their selection of towns for this gift, they have been guided by the number of applications for patents proceeding from each.

"This gift has in most cases laid the foundation of public free libraries where none previously existed. In some instances, where the local authorities hesitated to accept the works on account of the incidental expenses, the custody has been solicited and temporarily undertaken by scientific institutions, which have modified their by-laws to enable a free admission of the public daily to the library in which the works are deposited."

The same Report, after enumerating a list of the places which have received the works, says, "it is satisfactory to find that these national records of invention are especially consulted by that class whose skill in the improvement of manufactures is so essential to the maintenance of the commercial prosperity of this kingdom;" and adds the testimony of the librarians of several of the free libraries to the same effect.

Complete sets of the Commissioners' works have been sent to the Colonies; to many Foreign States; to the Patent Office, Washington; to the Aster Library, New York; to the Franklin Institution of Pennsylvania; to the Public Free Library, Boston, U.S.; and the Honourable Charles Mason, Commissioner of Patents for the United States, addressing the Commissioners of Patents in this country, writes as follows:—

"The admirable example you have set in publishing the specifications and drawings in full, and putting them on sale at a moderate price, so that all can easily provide themselves with what they need for private use, will ere long, I trust, stimulate our own Government to do the like. Nothing short of this in the way of publication can give permanent satisfaction."

A free library and reading-room has been opened at the office of the Commissioners of Patents, containing a large collection of works of reference, which the same Report states to be numerously attended by professional men, the agents of foreign and provincial inventors, and by practical mechanics and operatives; and Mr. Woodcroft has collected a large number of portraits of inventors and of models, illustrative of the history and progress of invention, which it may be hoped, at no distant period, will form a principal object in a national gallery of inventors and museum of inventions.

These and other undertakings, well suited to promote the advance of practical science and the interest of inventors, afford legitimate objects for the expenditure of the surplus funds levied on inventors; but when ample provision shall have been made for these objects, there will be a considerable annual surplus.

The amount paid by patentees during the last year was upwards of £83,000; and after the commencement of the payment of £100 at the expiration of the seventh year, the amount levied on inventors will not be found less than £100,000 per annum; a sum, which, as being levied on inventors and inventions, may reasonably be expected to be expended on objects in which inventors have some interest.

In reference to this branch of the subject, the following questions would appear to arise for consideration:—

1. Should the present scale of payment be maintained or reduced, so as to leave no great surplus beyond what may be necessary for the official expenses?
2. If the present scale be maintained, how should the surplus be appropriated?

It appears that the second payment of £50 before the end of the third year is not made in respect of more than about one-fourth of the whole number of patents issued, that payment being made on about 500 out of 2000 patents, so that 1500 are permitted to lapse; the cost of which in money to the patentees cannot be taken at less than £75,000, in addition to the expenditure of time and labour on the respective inventions. Can anything be done to diminish this loss beyond affording every facility for access to information as to what has been done before, and the improved education of the people?

In addition to these considerations and suggestions in connexion with the new system as recently established, and which are of a fiscal character, there are some other questions deeply affecting the interests of inventors and the advancement of practical science, which it would not be proper to close this Report without adverting to.

The Patent Law Reform of 1852 was never regarded as a final measure. It was but a first instalment obtained under great difficulty; it only laid the foundation of the superstructure yet to be raised. The following important questions of—1. improved protection to the property so created; 2. the amendment of existing patents and specifications, so as to save what is really new and useful according to the amendment of the Patent Law as effected by Lord Brougham in 1835; 3. the confirmation of an invention reinvented and introduced into successful use, according to the principle of the confirmation of rights effected by the same noble Lord; 4. the extension of the term of patents which have not yielded adequate remuneration to the inventor; 5. reward to a meritorious inventor, who from causes wholly beyond his control, has been a great loser by, or derived no benefit from a meritorious invention, from which the public have derived great benefit; 6. a system of compulsory licences under existing patents,—are questions, all of which were omitted advisedly by the promoters of the recent measure, their attention being directed mainly to the destruction of the existing, and the establishment of a new system of creating property in inventions.

These, with other amendments and matters of minor importance, which the experience of six years of the working of the new system has disclosed, will involve further legislation, and the consolidation and repeal of no less than sixteen statutes, or part of statutes, an object of great importance to every inventor.

Your Committee now remit this subject to the consideration of the Meeting of the British Association, deriving confidence from the belief that the times are not unfavourable for further action, and that the town and neighbourhood in which the Association is now assembled may appropriately claim to take a prominent part in the consummation of those reforms which have occupied the attention of so many previous Meetings.

On the Lead Mining Districts of Yorkshire.

By STEPHEN EDDY, *Carlton, Skipton.*

IN comparison with the vast coal fields and iron-stone beds of Yorkshire, the lead-producing district of this county seems trifling; yet in consideration of the large population dependent upon the mining and manufacture of lead, it necessarily claims our attention.

I cannot take it upon me to say, when lead mining was first commenced in this county; but that many veins were discovered and worked to some extent, at a very early period, is fully established, both by the Roman explorations frequently met with, and the discovery in the vicinity of Greenhow Hill, near Pateley Bridge, of two pigs of lead, inscribed with the name of the Emperor Domitian, and bearing date A.D. 82. It is not improbable, however, that the mines of these districts were worked at a still more remote period by the ancient Britons.

In the earlier age of lead mining, and indeed up to a comparatively recent period, the discovery of a vein entitled the party finding it to a grant, or licence to work, on a certain length of such particular vein, generally two meers; the meer being 28, 29, 30, or 32 yards, in different districts, respectively. The width of the ground granted was confined to a distance of 8 yards on each side of the vein. This was called the "Quarter Cord."

Thus, each vein formed a distinct mine, and from the well-known fact, that (though there is, generally speaking, a certain degree of parallelism maintained by the major part of the veins), in each of our mining fields, numerous intersections take place; the parties pursuing their allotted veins frequently found themselves within the quarter cord of the adjacent sett, and sometimes on their neighbour's vein. The result of such a system of holding, was not only to cramp the energies of the miner, from his not having a reasonable extent of ground for works of trial; but also to involve him in constant disputes and litigations with his neighbour.

The pernicious system of letting ground on a certain vein, with a given width on each side of such vein, was however continued to a comparatively recent date; when parties with capital becoming connected with the mines, and the works being so extended as to render the introduction of machinery advisable, the necessity for grants on a larger scale was so apparent, that small holders were by degrees disposed of, and the custom of granting setts (as they are termed) of certain extent, defined by fixed boundaries, which has been practised in Devon and Cornwall from a very early period, is now almost generally adopted in this county.

Generally speaking, the various lead mines which constitute such an important portion of the mineral treasures of Great Britain, are situated on rugged and barren elevations, and in this respect those of Yorkshire are not exceptions.

If we draw an imaginary line from Ilkley, bearing about 12° West of North, for a distance of 35 miles, and then parallel ones to it, through points 10 miles east and 10 miles west from the centre line, we shall in this area of 700 square miles, include the high and uncultivated districts bounding Airedale, Wharfedale, Nidderdale, Wensleydale, Arkendale and Swaledale; in which I believe all the lead mines in this county, that have been or are being worked to any extent, are situated.

The strata throughout the whole of this area, are (like those of the great lead-bearing districts of Northumberland, Cumberland, and Durham, and also of Derbyshire) the lower members of the Carboniferous Series.

Although the same class of rocks prevails throughout our lead-bearing districts, we do not always find each individual stratum to occur, even in mines in the immediate vicinity of each other; and when they do exist, their thickness is frequently found to vary considerably.

It is therefore impossible to make a section, that would correspond with every mining district, or even hold good throughout a single mining field.

Plate XVIII. figs. 1, 2, and 3, are sections of the strata sunk through in three of the shafts on the Grassington Mines in Wharfedale. From these it will be observed, that even in situations so close to each other, the thickness of the beds varies considerably.

The greatest thickness of Limestone yet proved at Grassington is 66 yards, whereas at the Cockhill Mines, near Pateley Bridge, only about 6 miles distant, it is found to be at least 180 yards thick.

In the metalliferous portion of the Carboniferous rocks, we have the Rake Vein, the Pipe or Tube Vein, and the lateral embedded, or Flat Vein.

The first has the appearance of a rent or fissure in the strata, extending to a great length, and generally to an unknown depth. The second, or Pipe Vein, has the form of an irregular tube, is met with in certain strata, (generally Limestone), and dips with the beds, or passes more or less diagonally through them, for a great length. The Flat Vein is seldom met with, except in connexion with some Rake Vein, but has always a position conformable to the stratum in which it is embedded.

The Rake Veins are by far the most numerous in every district, and the phenomena presented by them the most varied and complicated. The greater portion of our lead ore likewise is obtained from them.

The longitudinal course, or "bearing," of a Rake Vein, is seldom (if ever) a perfectly straight line; but, for the most part, it gives a tolerably direct bearing throughout its entire length.

The downward course of these veins varies considerably in the angles formed with the vertical. The "Hade," or inclination, is likewise more toward a horizontal position, in the soft or Argillaceous Beds, than in the more hard and solid rocks; and sometimes in passing a seam of Coal or of soft Clay, it takes the direction of the stratum for a greater or less distance. (See figs. 4, 5, and 6.)

The width of the vein is not uniform throughout its whole length; it frequently opens out from a width of a foot or two, to one of as many yards, and then contracts until it becomes a mere thread or joint.

At the Cononley Mine in Airedale, the vein is frequently found to vary from an inch or two in width, to five or six yards, and that, within a longitudinal distance of a few feet. The width of a vein varies also with a change of strata; it is much greater in the hard strata, where it has a more erect position than in the soft; it is generally more open in the Limestone than in the Gritstone, and very much contracted in the plate or shale. Frequently we find the vein to be 4 or 5 feet wide in the Grit or the Limestone, when it is scarcely perceptible in the plate.

The beginning or termination of a vein longitudinally, is seldom explored; where this has been done, the vein is found to ramify at acute angles, and the branches quickly terminate.

A remarkable instance of this recently occurred at the Grassington Mines. In these mines, three levels were being driven eastward on the Cavendish Vein, at the respective depths of 20, 37, and 50 fathoms from the surface. The 20-fathom level was in a stratum, locally known as the 'Top Grit;' the 37 in the 'Bearing or Main Grit;' and the 50-fathom level in the Limestone.

Each level was at the time yielding from 6 to 9 tons of rich lead ore from every fathom driven. Many parties who went underground in this mine, after some length of such rich ground had been explored, and while the levels continued to yield at that rate, concluded that ground was being laid open from which immense profits could be made, for many years to come; and they were correct, so far as they had an opportunity of judging; for, had the levels continued to open out such rich ground, no difficulty would have been found in making a profit of 40,000*l.* or 50,000*l.* a year from these mines.

Unfortunately a change soon took place. The first cause for apprehension noticed, was the wedge-like point of thin beds of Plate, introduced in different parts of the "Bearing Grit," in the 37-fathom level. As these became more numerous, and of greater thickness, the vein began to throw off branches on either side, and in the course of a few fathoms there was not a trace of the vein to be seen. As the upper and lower levels (the 20 and 50) approached the same perpendicular point eastward, the vein in each case ramified into numerous strings. First, one branch was followed, and then another, until they disappeared entirely. At about 60 fathoms eastwards from where all trace of this vein was thus lost, a "Crosscut" (that is, a level at right angles to the general bearing of the veins) was driven to some considerable distance both North and South of where it should have been intersected, had it continued eastward; but without discovering the slightest symptom of a vein.

The Rake Veins are generally found to be "Fault Veins." As a rule, the strata are lower on that side to which a vein hades or inclines, called the hanging wall, than on the one upon which it rests, known as the footwall of the vein. Thus a vein with the beds on the north side thrown up, will hade or underlie to the south. (See figs. 4 & 5.)

The extent of the throw, or difference of level of the corresponding strata, varies from a few inches to 20 or 30 fathoms; and such a difference is often met with when veins are in the immediate vicinity of each other. The extent of the throw is generally considered to denote the strength of the vein. A vein with a difference in the level of the strata of from 6 to 18 feet, is regarded by the miner with more favour than one with a greater or less throw. Such a throw is considered evidence of sufficient strength of vein to ensure its continuity at a moderate size, and not such as to destroy the effect which certain beds are supposed to produce, when they are found in the same horizontal line, on each side of the vein.

When rocks of a different character are brought into the same horizontal line, that is, when Gritstone on one side of the vein is opposed to Plate on the other, and Limestone to Gritstone, or Limestone to Shale, the veins are not often found productive of Lead ores. There are, however, many exceptions to this rule. At the Grassington Mines are two parallel veins, within 80 fathoms of each other, both throwing the south side down to such an extent, as to cause Plate to be opposed to Gritstone, Plate to Limestone, and Gritstone to Limestone, and so on throughout the whole depth explored on them. (See fig. 5.) So circumstanced, one of these veins yielded great abundance of ore, while the other proved to be totally barren.

We often find, when the vein occasions a throw of some two or three fathoms, that the ore does not extend above the change of strata on the hanging side, nor below the change on the lying or footwall; for instance, when the bed of Grit or Limestone is 10 fathoms thick, and the throw of the strata is 3 fathoms, we have only 7 fathoms in height of ore; but in some cases the ore is found to extend the full thickness of the bed with the addition of the extent of the throw. Diagram 4 represents a transverse section of such a vein in the Grassington Mines, from which considerable quantities of ore are now being raised.

The strata on each side of a vein are not only at different levels, but near the vein they have a different position, being bent upwards on the one side and downwards on the other. As a rule, the strata on the higher side are bent downwards to the vein, and on the depressed side from it. Thus, if in driving a crosscut southward, in search of a vein ranging east and west, we arrive at a point where the beds assume a faster dip, our approach to a vein that throws the strata down on the south side, is inferred; while, if in driving northward, the beds curve quickly upwards, we anticipate a vein with the north-side strata at a higher level. (See fig. 5.)

In each of our Lead-bearing districts, the strata consist of numerous alternating beds of Plate, Gritstone, and Limestone; forming the Yoredale Rocks of Professor Phillips.

The veins are found to traverse or pass through all these beds, but generally speaking, it is only in certain of them that Lead ore is found; the Limestone being the prevalently productive stratum in some districts, whilst in others the principal yield of ore is from the Gritstone. The Argillaceous Plates seldom yield ore; but there is an exception to this in the Cononley Mines, where bunches of ore have continued from the surface, to a depth of more than 30 fathoms; although the alternations of Plates and Gritstones are exceedingly numerous, and the Plates much thicker than the Gritstone beds.

From these facts it follows, that a rule, by which to calculate on metallic products from certain rocks, will not admit of general application; but we may carry it so far as to say, that in a given district, certain beds generally are, and others generally are not, productive.

Many veins, particularly in our more Northern fields, preserve a tolerably direct course for a considerable distance. The Old Gang Vein in Swaledale, for instance, has been worked for several miles in length, and can be traced to a much greater distance in nearly a straight line.

In our three Northern Mining Fields,—Swaledale, Arkendale, and Wensleydale—the veins appear to be more regular in size and direction, and the beds preserve a more uniform thickness, than in the three Southern Fields. In the former, likewise, the calcareous beds have been the principal sources of produce; whereas, in our Southern ones, the greater portion of the ore has been, and still is being produced, from the Gritstone.

There are other causes by which the productiveness of the veins appear to be influenced, that are peculiar to the Mines of our three Northern Dales, while certain characteristics more particularly pertain to our Southern Mining Fields. We may, therefore, for all the purposes of this paper, treat the Lead Mines of this county, as belonging to two great Mineral Districts, the Northern and the Southern.

In each district we have the Rake, the Pipe, and the Flat Veins. The ores from the Pipe and Flat Veins are generally found more fusible in the furnace, and to yield a higher per centage of lead, than those from the Rake Veins; and the ores from the Limestones (whether produced from the Rake, Pipe, or Flat Vein) are found to be more easily reduced, and to make a much better quality of metal for White Lead, than those from the Gritstone.

Here, I would refer to a correspondence, which took place some few months ago, in the columns of the 'Mining Journal,' on the subject of Slickensides. It was there asserted that Slickensides had never been met with in Gritstone. I am prepared to meet this assertion, by the production of the specimen obtained from the Gritstone in the Grassington Mines; and with the exception of one from the same place, which I gave to the late Duke of Devonshire, I much question there being a better specimen in the country.

The Slickensides first appeared at the point of junction of two veins, and continued their course in a perfectly straight line in the centre of the joint vein, for about 70 yards in length; or they might perhaps more correctly be said to have still divided the two veins, forming the North side of the one, and the South side of the other. (See fig. 7.)

We could have procured specimens from either side, with as good a surface as the one exhibited, but not so large. It was only from the South side that they could be obtained of any size, the other being so cracked horizontally, that it was seldom a piece could be broken off, more than an inch or two wide; in fact, the cracks on this side were almost as numerous as the striæ on the surface of the North.

The vein, throughout the whole length in which the Slickensides were found, maintained nearly a perpendicular position; and the striæ were as nearly horizontal. In many parts of the vein, we had the thickness of a foot of solid ore behind each face of Slickenside.

Many present will no doubt have read or heard of the phenomena reported to have attended the laying open of Slickensides in Germany; that the miner has at times been much frightened by the loud reports occasioned by the explosions.

When driving our level in the Slickensides, we generally worked forward on the North side, leaving the South, or strong side, standing for 6 or 8 yards in length; and on more than one occasion, the workmen spoke of the reports they heard, sometimes as loud as that of a small pistol. At such times, numerous places could be seen where pieces had been blistered, and blown away from the face of the Slickenside; which presented much the same appearance as a wall recently plastered with very imperfectly-slacked lime, but on a much larger scale.

The ore from a vein carrying much Slickenside, requires generally a higher temperature, and is altogether more refractory in the furnace than that from one free from it.

As a general rule, the greatest number of veins in each Mining district are found to run nearly parallel to each other. There are others that form angles more or less acute, with the predominant direction; which, in the Northern District, is a little North of East, and South of West; whilst in our Southern Fields, the general direction is North of West, and South of East.

Where the veins of the more usual line of direction are crossed by oblique or "caunter" veins, we frequently find the traversed ones to be shifted or thrown off their course, and often ramified by those so traversing; and sometimes they undergo a curvature on one side, near the cross vein.

As a rule, if the oblique or "caunter" vein be first met with on the right-hand side, the shift will be to the left; and if on the contrary, the heave will be to the right; or in other words, the vein is heaved on the side of the obtuse angle formed by the intersecting planes. (See fig. 8; A, B, A.)

To this rule there are however many exceptions, and a remarkable one occurred at the Grassington Mines, which is represented by Fig. 8. On finding the vein A A shifted, the level, as usual, was turned on the side of the obtuse angle, and driven forward on the vein B some considerable distance, till, despairing of finding the vein in this direction, and after carefully examining the surface, and some old works in the vicinity, we returned to the point of intersection, and began a level northward at nearly right angles to the traversed vein; which in course of time was found to be heaved or thrown backwards some 50 yards. (See fig. 8; A A, B B, A A.)

In heaves of this class, the veins are consequently lengthened; while they are shortened when thrown or shifted on the side of the obtuse angle.

The dislocation of one vein by another is likewise indicative of its anterior existence.

When one or both of the veins produce ore up to the point at which they meet, the yield is often increased by their junction. The extent of the angle formed by two veins is looked upon with some interest by the Miner; the more acute it is, the more favourable is their union considered to be for the production of metallic Mineral.

At Grassington, it is found that many of the direct veins are not heaved by the oblique or "caunter" ones, but are so split or ramified, that it is with difficulty they can be traced on the other side of the intersection. The usual course in such cases is to go forward on the "caunter" vein, some fathoms beyond the point of intersection, and drive a crosscut; when the branches are often found to have united, and the vein to be reconstructed.

When the displacement of the strata is so great as to cause beds of different mineral character to be opposed to each other, fragments of the enclosing rocks form a considerable portion of the contents of the vein.

The general composition of the veins is Calcareous Spar, Fluor Spar, Barytes, and occasionally Calamine. In some districts one of these minerals prevails, in others another.

A vein enclosed by regularly stratified Gritstone is productive, almost entirely, of Galena, which forms the principal yield of Lead Ores throughout the world. Cases have, however, occurred, when a somewhat thin stratum of Grit, superimposed on an Argillaceous Shale of moderate thickness, has exclusively contained large quantities of decomposing Galena, earthy Carbonates, and imperfectly crystallized Carbonates. In the former case, the ore lies mostly in more or less solid ribs, approximately parallel to the walls of the vein; while in the latter, the lode is found loosely filled with various sized pieces, in different stages of chemical decomposition.

When the beds of Gritstone and Shale are much broken and displaced (as is usual in the vicinity of an anticlinal axis, or contiguous to a line of extensive fault), or when the beds of Shale are individually thicker than the respective Gritstones, the vein throughout its productive depth principally yields irregular strings and small bunches of Galena; whilst its upper part mostly carries considerable deposits, of mixed rich and poor earthy, compact, and crystallized Carbonates.

In such ground, when the vein is very wide and encloses detached masses of Gritstone, or when the sides of the lode are much disturbed and broken, large crystals of the Carbonate are frequently found pressed flat upon the faces formed by the jointing and bedding planes of such Sandstone, for some distance from the body of the ore.

The Limestone beds usually favour the deposits of rich Galena in self lumps, or nodules of various sizes. These self lumps are often coated with an earthy white Carbonate, which is also frequently found filling the small interstices in the adjacent rock, and likewise as a deposit in the nests formed by those sudden enlargements and contractions so usual in veins traversing the Limestone beds. Not many of the other Lead Ores (which are seldom met with, and consequently of little commercial value) have been found in our Yorkshire Mines.

Minium is stated, in most Mineralogical works, to have been found on Grassington Moor; but I have never seen, nor heard of any from there, and certainly for twenty-six years past none has been found. The Phosphate and Arsenio-phosphate were formerly found at Grassington, principally in the Gritstone.

A small piece of native Lead has also been obtained from the Gritstone in those mines within the last four years.

In each district we have numerous mines; some, that a few years ago were highly productive, are now nearly exhausted; others, though but recently opened, are yielding well; and there is no doubt there are many rich veins yet undiscovered in both districts.

By far the greater portion of the present produce from the Northern district is from the Old Gang Mine, in Arkendale; and the Kell Head Mine, in Wensleydale; while the Grassington Mines in Wharfedale yield about two-thirds of the produce of the Southern district. The produce of the county in 1856 was 8933 tons of Pig Lead, or about $\frac{1}{8}$th of the total returns of the United Kingdom.

The difficulties and uncertainties which attend mining for Metallic Minerals are not generally known.

Many large and regular veins (although presenting very encouraging features) prove totally destitute of metallic mineral; others make rich deposits of ore, but of very limited extent; and in our most profitable mines, a considerable extent of barren ground must needs be opened, even on the best producing veins.

At the Cononley Mines, for instance, although profitable for many years past, the levels (which are very extensive) have laid open more than 20 fathoms of totally unmetalliferous, for every fathom of productive ground.

The Sections produced tend to show that Lead Mining in the secondary formation is more uncertain in its character than in the more primitive rocks. When ore is discovered in the latter, it is reasonably expected to continue upwards and downwards to some considerable extent; whereas, in a stratified country, and where the bearing beds are not individually thick, the ore at best will not exceed a few fathoms in height or depth, and moreover levels may be driven in certain beds without the slightest chance of success.

In one respect the stratified district offers the advantage. The nature and thickness of the bearing beds, and the inclination of the strata being known, we can generally determine the elevation for commencing an Adit, or water level, to drain the productive parts of the veins; and thus avoid the cost of engine power for pumping, and other expenses.

Mining for Metallic Minerals, whether in the primitive or secondary formation, is of a much more uncertain and speculative character than that for Coal. In the Coal Measures, we can ascertain at a moderate expense, by boring, whether seams of Coal exist; and if existing, their thickness. This being learnt, an approximate estimate of the quantity of saleable Coal in a given area, and the cost of its get, is no difficult matter.

With the Rake and Pipe Veins of the Lead Fields, the case is different. A vein which generally approaches the perpendicular, rather than otherwise, presents little chance of being probed by boring; and even should it be pierced, the mineral capable of extraction through a borehole would afford very unsafe data by which to judge the value of the vein. The hole might quite possibly pass through the only portion of ore contained within many fathoms; or, with an equal possibility, penetrate the poor part of a vein, which at any other point would have yielded widely different data.

Mineral veins may be, and frequently are, discovered (in places where the surface of the rock is to be seen) by the fracture and interruption in the regularity of the strata.

In all Mining districts, but especially in a stratified country, the phenomena presented by veins, their frequent heaves and dislocations, and their varied appearances when bounded by different rocks, call for very close attention; and even a dependence upon knowledge acquired in one district, may prove fatal in another.

The Miner should be perfectly acquainted with the nature of those substances, which it is his daily task to seek in the bowels of the earth,—as well as with those which, though perhaps worthless in themselves, generally indicate the presence or absence of the immediate objects of his search. Long and practical experience, combined with a knowledge of Geology and Mineralogy, can alone furnish him with this requisition; and is therefore essential to success.

On the Collapse of Glass Globes and Cylinders. *By* W. FAIRBAIRN, *F.R.S.*

AT the Meeting of the British Association last year, a paper was read upon the Collapse of Cylindrical Wrought-iron Riveted Tubes by a uniform external force. These experiments upon a ductile and fibrous material, led to some novel and important results, and suggested the propriety of similarly testing the resisting powers of a perfectly homogeneous crystalline and rigid material, in order that our knowledge of the laws which govern the resistance of vessels to collapse, might be confirmed and extended.

For this purpose, glass was the material selected, not only on account of its fulfilling better than almost any other material the conditions sought for, and from the ease with which it could be manufactured into the required forms; but also because it was hoped that the results would be practically of value in those cases in the arts and in experimental science in which it is so extensively employed.

The experiments were conducted in a similar manner to those upon iron. Some glass cylinders and globes were procured direct from the glass-house, blown out of good flint-glass. The open ends of these were then hermetically sealed by the blow-pipe, and they were placed in a strong wrought-iron vessel, capable of sustaining a pressure of 2500 lbs. per square inch. Water was then pumped in by means of a force-pump, and the pressure was recorded by a Schæffer gauge. The point of rupture was indicated by an explosion within the vessel, and by the sudden decrease of pressure.

The first experiments were upon glass globes, intended to be perfectly spherical, but in most instances somewhat flattened upon the side opposite to that from which they were blown. Notwithstanding, however, this ellipticity, some of the globes bore enormously high pressures, especially when the extreme tenuity of the glass is considered, amounting to from one to two hundredths of an inch in thickness only.

TABLE I.—Strength of Glass Globes to resist a uniform external pressure.

Mark.	Diameters.		Thickness.	Collapsing pressure.
	inches.	inches.	inch.	lbs. per square inch.
L	5·05	4·76	0·014	292
M	5·08	4·70	0·018	410
K	4·95	4·72	0·022	470
B	5·60	—	0·020	475
N	8·22	7·45	0·010	35
C	8·20	7·30	0·012	42
D	8·20	7·40	0·015	60

It will be seen that, notwithstanding the extreme thinness of the glass, the pressures range as high as 475 lbs. per square inch over every square inch of surface, equivalent to a total pressure of 20 tons upon a $5\frac{1}{2}$-inch globe $\frac{1}{50}$th of an inch thick, before it was fractured.

Unfortunately the 8-inch globes were all elliptical to a serious extent, and hence in these the collapsing pressure was greatly reduced, ranging from 35 to 60 lbs. per square inch only.

The next results are upon glass cylinders, blown with hemispherical ends. In the experiments upon iron, the remarkable law had been deduced that the strength of cylindrical vessels of that material, exposed to a uniform external pressure, varied inversely as the length. Thus with vessels precisely similar in other respects, one twice the length of another bore only half the pressure, one three times the length bore only one-third of the pressure, and so on. From the following experiments it will be seen that a similar law applies in the case of homogeneous glass cylinders.

TABLE II.—Strength of Glass Cylinders to resist a uniform external pressure.

Mark.	Diameter.	Length.	Thickness.	Collapsing pressure per square inch.
	inches.	inches.	inch.	lbs.
E	4·06	$13\frac{3}{4}$	·043	180
G	4·02	$13\frac{3}{4}$	·064	297
H	3·98	14	·076	382
P	4·05	7	·046	380
Q	4·05	7	·034	202
T	3·09	14	·024	85
R	3·08	14	·032	103
S	3·25	14	·042	175

These cylinders, though of high resisting powers, sustain considerably less pressure than the globes. Comparing cylinders E and P, 14 and 7 inches long respectively, and of the same diameter and thickness of glass, we find the longer was crushed with about half the pressure which was requisite to collapse the shorter cylinder, which is a confirmation of the law deduced for iron tubes.

The general formula for the globes takes the form of the following equation,

$$P=\frac{C\times t^{\frac{3}{2}}}{D^{3\cdot 17}},$$

P being the collapsing pressure in lbs. per square inch; D=diameter; t=thickness of glass. Similarly, putting L=length, the formula for the cylinders is

$$P=\frac{C\times t^{\frac{3}{2}}}{D\times L},$$

which is precisely similar to that for iron tubes.

Report on the Marine Fauna of the South and West Coasts of Ireland. By E. Perceval Wright, *M.B., A.B., F.L.S., M.R.I.A., Director of the Museum, and Lecturer on Zoology, University of Dublin; and* J. Reay Greene, *A.B., M.R.I.A., Professor of Natural History, Queen's College, Cork.* Part I. (1858).

At the last Meeting of the British Association, a Committee consisting of Drs. E. Perceval Wright, Melville, and Kinahan, was appointed to investigate the marine Zoology of the south and west Coasts of Ireland.

Professor J. Reay Greene and Dr. Carte of Dublin were subsequently added to the Committee.

The region marked out for their observations extends from Carnsore Point in the Co. of Wexford, to Gweedore Bay in the Co. Donegal, and embraces a coast line of several hundreds of miles. It was evident that so vast a district could only be investigated by the labours of several years, and hence, on mature deliberation, the Committee determined to devote themselves and the money grant placed at their disposal by the Council for 1858, to investigate parts of the Cos. Waterford, Cork, and Kerry; reserving the Coasts of Clare and Galway for the next ensuing summer, and those of Mayo, Sligo, and Donegal for another year; hoping, at the expiration of this period, to be able to communicate to the British Association a Report, which, with the joint Reports from the North of Ireland and Dublin Bay Dredging Committee, will enable us to draw up a final Report on the Irish Marine Fauna, which shall be entitled to act a second part to that by the late Professor E. Forbes "On the investigation of the British Marine Fauna," published in 1850.

Such being our intention, we wish it to be understood that the present Report is merely provisional, and that we refrain from deducing any theories from the facts observed, until we have the entire district examined.

Early in July 1858, we proceeded to investigate the first selected region, and a list of the stations from which the coast at each side was explored is given, *i. e.* 1. Carnsore Point; 2. Saltees; 3. Hook Head; 4. Dunmore; 5. Tramore; 6. Youghal; 7. Cork Harbour; 8. Kinsale; 9. Rosscarberry; 10. Castletownsend; 11. Baltimore; 12. Cape Clear Island; 13. Skull; 14. Crookhaven; 15. Glengariff; 16. Berehaven; 17. Ardgroom; 18. Cahersiveen; 19. Valentia; 20. Dingle; 21. Ventry; 22. the Blasquet Islands.

Several portions of this district had from time to time been investigated by various Irish naturalists, and previous to setting out on our explorations, we carefully noted the result of their labours, in order that we might corroborate all doubtful localities given by them, and also have the benefit of their past experience; the localities so investigated, were Youghal by the late Dr. Ball, Cork Harbour by J. Vaughan Thompson and others, Courtmacsherry and Bantry Bays by Professor Allman, Dingle Bay by W. Andrews, and Valentia by Professor Kinahan.

Considering that we could not gain a correct knowledge of the Fauna without devoting a good deal of attention to "shore collecting," we took frequent occasion, at the period of low tides, to investigate the littoral zone: and to this fact may be ascribed the discovery of a large number of new Irish Zoantharia, and many interesting Nudibranch Mollusca.

The geologic structure of the coast, for the most part Devonian and Silurian, is such, that "shore collecting" cannot be prosecuted unless with the assistance of boats: as sheer precipices, often hundreds of feet high and rising perpendicularly out of the water, quite preclude access to the very fertile fields of marine zoology which may be found in the tide-worn caverns at their base.

In many places, too, small rocky islets, covered at every successive tide, were proved well worthy of diligent search.

While we paid a good deal of attention to this latter kind of investigation, we yet did not neglect the as important one of "dredging," The smallness of our grant, added to the extreme expense which would attend on deep-sea dredging in such remote parts of Ireland, prevented us from exploring any depth beyond thirty or forty fathoms. We, however, hope on a future occasion to be enabled to undertake a series of deep-sea dredgings on the west coast, by the kind assistance of some yachting friends.

The commonest sea bottom we met with, was one formed of a coarse sand, chiefly made up of the débris of decaying Nullipore and broken fragments of Trophon, Natica, Rissoa, Odostomia, &c. This sand particularly abounds in Bantry Bay; it is most extensively used for fertilizing the land, being dredged for this purpose in enormous quantities. Marine animals seem to avoid this "Coral sand," and with the exception of *Hippolyte varians*, even the 'Shrimps' appeared to us to abandon it. Next, we met with vast tracks of heavy compact sand, chiefly tenanted by the Crangonidæ and Palæmonidæ, diversified here and there with large patches of weedy ground which abounded with animal life.

Many of the large harbours were very muddy, and abounded with sponges, &c., which sometimes reached gigantic dimensions.

The Cape Clear Island, the most southern,—and the Blasquet Islands, the most western land in Ireland, with Bere Island, were carefully examined; but their sides present such high and unbroken walls to the ocean, and they are so exposed to its continual swell, that they were not found particularly productive.

To enumerate in detail the various species of the marine Fauna met with, would be at the present immature. But we would wish to call attention to some interesting forms that presented themselves, and append a list of the Zoantharia and Echinodermata as specimens of the richness of the Fauna.

On quiet days, when the Atlantic was moderately calm, nothing could exceed in beauty and numbers the Medusæ—fleets of Æquorea sailed past, accompanied by *Thaumantias globosa*, *Thompsoni*, *confluens*, and many others; this last-mentioned species, discovered by the late Professor Edward Forbes, is remarkable for the peculiar arrangement of its reproductive glands, which are placed so high up in the gastro-vascular canals, as to present the appearance of a bright red cross, shining conspicuously through the transparent disk, when the animal is seen floating beneath the surface of the water.

New forms of Slabberia, Oceania, &c., occurred in the western entrance of Berehaven, as also many specimens of *Willsia stellata.*

Except for their abundance, the following Ctenophora would hardly merit notice, viz. *Cydippe pileus* and *pomiformis*, *Mnemea Norvegica*, and *Beröe ovata.* This latter swam in shoals; several of the specimens being of a very large size and of a bright roseate hue, frequently diversified with a play of iridescent colours. In Berehaven Harbour we also obtained an apparently new species of Tomopteris; its otherwise transparent body glittered with many bright sherry-coloured spots, and we were enabled to investigate with some care the anatomy of this very anomalous creature.

The List of Zoantharia appended (List B) will show the species that occurred. In some parts of the coast, as off Crookhaven and Dingle, the whole surface of the rocks for many square yards was covered with specimens of *Corynactis viridis*, so far belying its specific name as to appear of the most brilliant purple, as often as of a bright green, varied with many of a rich peach colour. Every excavation that the waves had worn in the slaty Devonian, was inhabited by *Sagartia venusta*, *S. rosea*, and others of the genus; and we observed that at Parkmore Point, near Venty, *Tubularia indivisa* abounded in such quantities, that in one place a piece of rock about 20 feet long by 10 or so broad, and covered by 1 or 2 feet of water, was one dense forest of this interesting Hydrozoon; others of this latter division were observed, but details thereof are reserved for a future occasion.

Among the Echinodermata, we may mention that *Uraster glacialis* occurred very commonly, and several specimens were dredged, which measured 32 inches in diameter; *Luidia fragillissima* and *Asterias aurantiaca* were not unfrequent. *Amphidotus roseus* occurred in Bantry Bay. From the list appended, it will be seen that nearly all the Asteriadæ, with but few exceptions, have been obtained on the coast of Ireland.

Cribella rosea and *Goniaster Templetoni* have been taken by Dr. Ball on the Nymph Bank off Waterford, and at Youghal. Several new species also occurred to us. We think we have discovered the "first appearing" on the south coast of the *Echinus lividus*, on some sunken rocks out at sea; and it appears to us that a curious relation exists between the vertical and geographical distribution of the species in question, since the higher the latitude in which it is found, the shallower the water it would appear to frequent. We have been led to this conclusion from observations made by us on its occurrence around the west and south coasts of Ireland. At Dingle, for example, it lives and thrives high up in the Littoral Zone; whereas about the Cape Clear district, it loves the deep rock pools, where it is only exposed to view at the very lowest tides, and even then with from 10 to 15 feet of water always over it. The rare *Echinus Flemingii* has been taken by Dr. Ball at Youghal. (See List A.)

Of the Crustacea a long list could be furnished, but we would only allude to the capture of the various species of Ebalia on sandy ground in Castletownsend and Berehaven; of *Xantho rivulosa* at Valentia, where it was taken in 1856 by Dr. Kinahan; and *Pirimela denticulata* in Dingle by Wm. Andrews, Esq. *Galathea Andrewsii*, a species recently added to science by Dr. Kinahan, was dredged in the greatest abundance.

Of the Mollusca little mention need be made,—*Doris flammea*, *coccinea*, the two *Hermæas* recorded in Alder and Hancock, *Eolis Farrani*, &c. were found, the latter three very abundantly; a large number of Tunicata awarded our diligent search with several probably new species. *Calyptræa sinensis* and *Ianthina communis* may be alluded to among the Gasteropods, with *Amphysphyra hyalina*, *Tornatella fasciata*, *Philine quadrata*, &c. *Aplysia hybrida* might be seen browsing in herds on the *Codium tomentosum*, which at Berehaven grows most luxuriantly. *Arca tetragona* occurred at Ardgroom, *Venus casina*, &c. with *Pectunculus glycimeris*, in Bantry Bay.

Amphioxus lanceolatus was taken in Berehaven, one specimen of which survived its capture for many days, despite of being carried in a glass vessel nearly 200 miles. William Andrews records the following rare fish as occurring off Dingle: *Capros aper*, *Sebastes Norvegicus*, *Cottus Grœnlandicus*, *Morrhua minuta*, and *Raniceps trifurcatus*; both *Lepidogaster cornubiensis* and *bimaculatus* were taken by us at the shore of Cape Clear Island.

In conclusion, we would ask for a renewal of the grant for the year 1859 from the Council, trusting to continue our exploration of this interesting region with unabated zeal, and with a sure confidence that the result of our labour will prove of some service to those who, like us, are engaged in the pleasant task of observing and recording the many created beings, which, nurtured and preserved in life by the great world of waters alike with it, proclaims the existence of an Almighty and Omnipotent God.

List of Echinodermata (A).

	N.	N.E.	E.	S.	S.W.	W.	N.W.
1. Comatula rosacea	......	*	*	*	*	*	
2. Ophiura texturata	......	*	*	*	*		
3. „ albida	......	*	*	*	*	*	
4. Ophiocoma neglecta	......	*	*	......	......	*	
5. „ Leachii (n. sp. J. G.)	......	......	......	*			
6. „ Ballii	......	......	*				
7. „ filiformis	......	*	*	*	......	*	*
8. „ brachiata	......	*					
9. „ granulata	......	*	*				
10. „ bellis	......	*	*	*	......	*	
11. „ rosula	......	*	*	*	*	*	
12. „ minuta	......	*	*	*	*	*	
13. „ (n. sp. G. & W.)	......	......	......	*	*		
14. Uraster glacialis	......	*	*	*	*	*	*
15. „ rubens	......	*	*	*	*		
16. „ violacea	......	*	*	*	*	*	
17. „ hispida	......	*	*	*	*	*	
18. Cribella oculata	......	*	*	*	*	*	
19. „ rosea	......	......	*				
20. Solaster endeca	......	*	*	*			
21. „ papposa	......	*	*	*	*	*	
22. Palmipes membranaceus	......	*	*	*			
23. Asterina gibbosa	......	......	*?	*	*	*	
24. Goniaster Templetoni	*	*	*	......	......	*	
25. Asterias aurantiaca	*	*	*	*	*	......	*
26. Luidia fragillissima	......	......	......	*	*	*	
27. Echinus sphæra	*	*	*	*	*	*	*
28. „ miliaris	*	*	*	*	*	*	
29. „ Flemingii	......	......	......	*			
30. „ lividus	*	......	......	......	*	*	*
31. Echinocyamus pusillus	......	*	*	*	*	*	
32. Spatangus purpureus	......	*	*	*			
33. Brissus lyrifer	......	......	......	......	*		
34. Amphidotus cordatus	......	*	*	*	*	*	
35. „ roseus	......	*	*	*	*	*	
	1	2	3	4	5	6	7

N.B. We purposely exclude from this List all reference to the Holothuriadæ, the species of which stand much in need of further elucidation. We have also given the distribution, as far as it was known to us, all round Ireland, both in this List and the following one on Zoantharia.

List of Zoantharia (B).

	N.	N.E.	E.	S.	S.W.	W.	N.W.
1. Actinoloba dianthus	*	*	*	*	*	*	*?
2. Sagartia bellis..........................	*	*	*	*	*	*	*?
3. „ miniata	......	......	......	*	*		
4. „ rosea	......	......	......	*	*		
5. „ ornata	......	......	......	......	*		
6. „ venusta	......	......	......	*	*	*	
7. „ nivea	......	......	......	......	*		
8. „ sphyrodeta	......	......	......	......	*		
9. „ pura.....................................	......	......	......	......	*		
10. „ coccinea	......	......	......	......	......	......	*?
11. „ troglodytes	......	*	*?				
12. „ viduata	......	*	*	......	......	*	
13. „ parasitica............................	......	......	......	......	*		
14. „ hastata (n. sp. E. P. W.)	......	......	......	......	*		
15. Adamsia palliata........................	......	*	*	*	*		
16. Anthea cereus............................	*	*	*	*	*	*	
17. Actinia mesembryanthemum.........	*	*	*	*	*	*	*
18. Bunodes gemmacea	......	......	......	*	*		
19. Tealia crassicornis	......	*	*	*	*	*	
20. „ Greenii (n. sp. E. P. W.)	......	......	......	*			
21. Corynactis viridis(Allmanni,E.P.W.)	......	*	......	*	*	*	
22. „ heterocera	......	......	......	......	*		
23. Ilyanthus Scoticus	......	......	*				
24. Turbinolia milletiana.................	......	......	......	......	......	*	
25. Zoanthus Couchii	......	*					
26. Cyathina Smithii	*	*	*	*	*		
27. SphenotrochusWrightii (n.sp.Gosse)	......	*					
	1	2	3	4	5	6	7

Total number of species of Echinoderms 35, or about two-thirds of the British list; and of the Zoantharia 27, or about half the number recorded as occurring in England and Scotland. This difference will, we trust, be greatly diminished in a few years. Both lists have been brought down to the latest dates, several species having been added while the MS. was passing through the press.

The districts marked from 1 to 7, are given as first introduced by one of the authors in the "Proceedings of the Dublin University Zoological and Botanical Association," vol. i. p. 176, and are briefly as follows:—

1st Province, North.—From Tory Island or Horn Head, on the mainland, to Rathlin Island or Fair Head, embracing the two extensive Loughs, Swilly and Foyle, and parts of the counties of Donegal, Londonderry, and Antrim.

2nd Province, North-East.—From Fair Head to Downpatrick, at the entrance of Strangford Lough, embracing Belfast and Strangford Loughs, and parts of Antrim and Down.

3rd Province, East.—From Downpatrick to Carnsore Point, in the county of Wexford, embracing Dundrum, Dundalk, and Dublin Bays, and parts of the counties of Down, Louth, Meath, Dublin, Wicklow, and Wexford.

4th Province, South.—From Carnsore Point to Cape Clear, county of

Cork, with the fine harbours of Waterford, Dungarven, Youghal, Cork, and Kinsale, and parts of the counties of Wexford, Waterford, and Cork.

5th Province, South-West.—From Mizen Head to Kerry Head, or the mouth of the Shannon, embracing Bantry, Dingle, and Tralee Bays, the Kenmare River, and parts of the counties of Cork and Kerry.

6th Province, West.—From Loop Head, county of Clare, to Erris Head, on Mullet Island, at the extreme north-west of Mayo, embracing Galway, Clare, and Blacksod Bays, the Isles of Arran, Clare, Achill, and Mullet, and parts of the counties of Clare, Galway, and Mayo.

7th Province, North-west.—From Erris Head to Horn Head, embracing Killala, Sligo, and Donegal Bays, and parts of the counties of Mayo, Sligo, and Donegal.

"These seven Provinces might be easily subdivided, but I think this is not advisable; indeed, I am rather doubtful of the propriety of keeping either the 2nd or 5th Province: but still we find species peculiar to each of these localities, or at least occurring in them, and not generally found in the others: thus, *Echinus lividus* occurs in Province 5, but hardly, if at all, in Province 4. I need hardly justify the utility of making these Provinces; their convenience, when referring to geographical distribution, is obvious; as by saying in which of these Provinces an animal occurs, we at once arrive at an idea of its distribution in a much shorter manner than enumerating the counties it occurs in. I have hesitated to call the Provinces Boreal, Lusitanian, &c., thinking the time has not yet arrived for so doing. The Dredging Committees on the east, north, and south-west of Ireland will doubtless in time enable this to be done. I have only to hope this enumeration may be adopted, as it will render comparison so very easy."

On Experiments on the Measurement of Water by Triangular Notches in Weir Boards. *By* JAMES THOMSON, *A.M., C.E., Professor of Civil Engineering, Queen's College, Belfast.*

THE experiments proposed to be comprehended in the investigations to which the present interim Report relates, have for their object to determine the suitableness of triangular (or V-shaped) notches in vertical plates for the gauging of running water, instead of the rectangular notches in ordinary use. The ordinary rectangular notches, accurately experimented on as they have been, at great cost and with high scientific skill, in various countries, with the view of determining the necessary formulas and coefficients, for their application in practice, are for many purposes suitable and convenient. They are, however, 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. If the rectangular notch is to be made wide enough to allow the water to pass 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. To remove, in some degree, this objection, gauges for rivers or streams are sometimes formed in the best engineering practice, with a small rectangular notch cut down below the general level of the crest of a large rectangular notch. If, now, instead of one depression being made for dry-weather use, in a crest wide enough for use in floods, we conceive of a large number of depressions extending so as to give to the crest the appearance of a set of steps of stairs, and if we conceive the number of such steps to become infinitely great, we are led at once to the conception of the triangular, instead of the rectangular notch. The principle of the triangular notch being thus arrived at, it becomes evident that there is no necessity for having one side of the notch vertical and the other slanting; but that, as may in many cases prove more convenient, both sides may be made slanting, and their slopes may be alike. It is then to be observed, that by the use of the triangular notch with proper formulas and coefficients derivable by due union of theory and experiments, quantities of running water, from the smallest to the greatest, may be accurately gauged by their flow through the same notch. The reason of this is obvious, from considering that in the triangular notch, when the quantity flowing is very small, the flow is confined to a small space admitting of accurate measurement; and that the space for the flow of water increases as the quantity to be measured increases, but still continues such as to admit of accurate measurement.

Further, the ordinary rectangular notch, when applied for the gauging of rivers, is subject to a serious objection from the difficulty, or impossibility, of properly taking into account the influence of the bottom of the river on the flow of the water to the notch. If it were practicable to dam up the river so deep that the water would flow through the notch as if coming from a reservoir of still water, the difficulty would not arise. This, however, can seldom be done in practice; and although the bottom of the river may be so far below the crest as to produce but little effect on the flow of the water when the quantity flowing is small, yet when the quantity becomes great, the "*Velocity of Approach*" comes to have a very material influence on the flow of the water, but an influence which it is usually difficult, if not impracticable, to ascertain with satisfactory accuracy. In the notches now proposed, of triangular form, the influence of the bottom may be rendered definite, and such as to affect alike (or at least by some law that may be readily determined by experiments) the flow of the water when very small, or when very great, in the same notch. The method by which I propose that this may be effected, consists in carrying out a floor starting exactly from the vertex of the notch, and extending both up stream and laterally so as to form a bottom to the channel of approach, which will both be smooth, and will serve as the lower bounding surface of a passage of approach unchanging in form while increasing in magnitude at the places at least which are adjacent to the vertex of the notch. The floor may either be perfectly level, or may consist of two planes whose intersection would start from the vertex of the notch, and, as seen in plan, would pass up stream perpendicularly to the direction of the weir board, the two planes slanting upwards from their intersection more gently than the sides of the notch. The level floor, although theoretically not quite so perfect as the floor of two planes, would probably, for most practical purposes, prove the more convenient arrangement. With reference to the use of the floor, it may be said, in short, that by a due arrangement of the notch and the floor, a discharge orifice and channel of approach may be produced, of which (the upper surface of the water being considered as the top of the channel and orifice) the form will be unchanged or but little changed, with variations of the quantity flowing;—very much less certainly than is the case with rectangular notches.

The laws regulating the quantities of water flowing in such orifices as have now been described, come naturally next to be considered. Without, however, in the present interim Report, attempting to enter on a detailed discussion of theoretical considerations on this subject, I shall here merely advert briefly to the principal results and methods of reasoning.

By theory I have been led to anticipate that the quantity flowing in a given notch should be proportional, or very nearly so, to the $\frac{5}{2}$ power of the lineal dimensions of the cross section of the issuing jet, or to the $\frac{5}{2}$ power of the head of water over the vertex of the notch. This head is to be understood, in the case of water flowing from a still reservoir, as being measured vertically from the level of the water surface down to the vertex of the notch; or, in the case of water flowing to the notch, with a considerable velocity of approach over a floor arranged as above prescribed, the head is to be considered as being measured vertically from the water surface where the motion is nearly stopped by the weir board, at a place near the board, but as far as may be found practicable from the centre of the notch. The law here enunciated, to the effect that the quantity flowing should be proportional to the $\frac{5}{2}$ power of the head, I consider should hold good rigidly in reference to water flowing by a triangular notch in a thin vertical plate from a large and deep reservoir of still water, if the water were a perfect fluid, free from viscidity and friction, and free from capillary attraction at its surface, and from any other slight disturbing causes that may have minute influences on the flow, the flow being supposed to be that due simply to gravitation resisted by the inertia of the fluid. The like may be said of water flowing from triangular notches with shallow channels of approach, having floors as described above, when due attention is given to make the passages of approach so as really to remain unchanged in form for a sufficient distance from the notch, while increasing in magnitude as the flow increases (such being supposed, according to my theory, to be possible); and if due attention be paid to measuring the heads in all cases in positions similarly situated with reference to the varying dimensions of the issuing streams.

In illustration of these statements, or suppositions, I would merely say that if two triangular notches, similar in form, have water flowing in them at different depths but with similar passages of approach, the cross sections of the two jets at the notches may be similarly divided into the same number of elements of area; and that the areas of the corresponding elements will be proportional to the squares of the lineal dimensions of the cross sections, or, as from various considerations may readily be assumed, proportional to the squares of the heads; also the velocities of the water in the corresponding elements may be taken as proportional to the square roots of the lineal dimensions, or to the square roots of the heads. From these considerations, supported by numerous others, it appears that the quantities flowing should be proportional to the products of the squares of the heads into their square roots, or to the $\frac{5}{2}$ powers, as already stated.

The friction of the fluid on the solid bounding surfaces of the passages of approach where the water moves rapidly adjacent to the notch, may readily be assumed, from all previous experience in similar subjects, not to have a very important influence even on the absolute amount of the flow of the water; and if we assume (as is known to be nearly the case for high velocities, such as occur in notches used for practical purposes, unless unusually small) that the tangential force of friction of the fluid, per unit of area of surface flowed along, is proportional to the square of the velocity of flow, it follows by theory that the friction, although slightly influencing the absolute amount of the flow, will not, according to that assumption, at all interfere with its proportionality to the $\frac{5}{2}$ power of the head, and this condition will very nearly hold good if the assumption is very nearly correct.

How closely the theory thus briefly sketched may be found to agree with the actual flow of water will be a subject for experimental investigation;

and whatever may be the result in this respect, the main object must be to obtain, for a moderate number of triangular notches of different forms, and both with and without floors at the passage of approach, the necessary coefficients for the various forms of notches and approaches selected, and for various depths in any one of them, so as to allow of water being gauged for practical purposes, when in future convenient, by means of similarly-formed notches and approaches. The utility of the proposed system of gauging, it is to be particularly observed, will not depend on a perfectly close agreement of the theory described with the experiments, because in respect to any given form of notch and approach, a table of experimental coefficients for various depths, or an empirical formula slightly modified from the theoretical one, will serve all purposes. To one evident simplification in the proposed system of gauging, as compared with that by rectangular notches, I would here advert, namely, that in the proposed system, when once the form of the notch and channel of approach is fixed for gauging any set of streams, the quantity flowing comes to be treated as a function of only one variable, namely, the measured head of water; while in the rectangular notches it is practically treated as a function of at least two variables, namely, the head of water and the horizontal width of the notch; because in practice it would be inconvenient, if not impossible, to select any single width of notch, or any moderate number of widths of notches, for general use, for very varied quantities of water. It is commonly also a function of a third variable, very difficult to be taken into account, namely, the depth from the crest of the notch down to the bottom of the channel of approach; which depth must vary in its influence with all the varying ratios between it and the other two quantities of which the flow is a function.

The proposed system of gauging also gives facilities for taking another element into account which often arises in practice; namely, the influence of back water on the flow of the water in the gauge, when, as frequently occurs in rivers, it is found impracticable to dam the river up sufficiently to give it a clear overfall, free from the back or tail water. For any given ratio of the height of the tail water above the vertex of the notch, to the height of the head water above the vertex of the notch, I would anticipate that the quantities flowing would still be, approximately at least, proportional to the $\frac{5}{2}$-power of the head as before; and a set of coefficients would have to be determined experimentally for different ratios of the height of the head water to the height of the tail water above the vertex of the notch.

With the aid of the grant placed at my disposal by the Association at last year's meeting, for the purposes of these researches, I have got an experimental apparatus constructed and fitted up at a place a few miles distant from Belfast, in Carr's Glen, on the grounds of Mr. Neeson, who has kindly afforded me all the necessary facilities regarding the water supply and the site for the experiments; and I have got some preliminary experiments made on a right-angled notch in a vertical plane surface, the sides of the notch making angles of 45° with the horizon, and the flow being from a deep and wide pool of quiet water, and the water thus approaching the notch uninfluenced by any floor or bottom. The principal set of experiments as yet made were on quantities of water varying from about 2 to 10 cubic feet per minute; and the depths or heads of water varied from 2 to 4 inches in the right-angled notch. From these experiments I derive the formula $Q = \cdot 317\ H^{\frac{5}{2}}$; where Q is the quantity of water in cubic feet per minute, and H the head as measured, vertically, in inches, from the still-water level of the pool, down to the vertex of the notch. This formula is submitted, at present temporarily, as being accurate enough for use for 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; but as being, of course, subject to amendment by more perfect experiments extending through a wider range of quantities of water.

Out of the grant of £10 from the Association for these experiments, the amount for which I have hitherto had to apply to the Treasurer as having been expended in them is £8 0*s.* 4*d.*; which leaves a balance remaining of £1 19*s.* 8*d.*

It will be readily observed, that the experimental investigations indicated in the foregoing report as desirable, are such as would require for their completion, and extension to large flows of water, a great expenditure both of time and money, like as has already been the case with researches on the flow of water in rectangular notches. All that I can myself for the present propose to attempt, is to open up the subject with experiments on moderately small flows of water; and with this view, I would be glad to be aided, by a further grant from the Association, in continuing experiments of the kinds already undertaken.

Report of the Committee on the Magnetic Survey of Great Britain. *By* Major-General Sabine.

The Committee are glad to be able to state that the Survey has made good progress in the course of the present year. Mr. Welsh has completed the Survey of Scotland and its adjacent islands, by adding observations at a sufficient number of points on the islands to the north and west of the main land to those he had made in Scotland itself in 1857. General Sabine has employed himself in North and South Wales; and Dr. Lloyd, having associated with himself Professors Joseph Galbraith and Samuel Haughton, and George Johnstone Stoney, Esq., has obtained observations on the course of the isoclinal and isodynamic lines over Ireland generally.

There is probably another year's work before the Survey will be so far advanced that its different parts can be coordinated, preparatory to the final account being prepared for presentation to the Association. In the mean time Dr. Lloyd is desirous that the names of Messrs. Galbraith, Haughton, and Stoney should be added to those of the Committee named in 1856.

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, 1857. *By* Michael Connal, *Esq., and* William Keddie, *Esq., Glasgow.*

The following returns have been obtained from a careful examination of the Clyde Bill of Entry, printed by the Custom House authorities at Glasgow. The returns embrace only substances imported from foreign countries, exclusive of those received "coastwise." From the vague and often inaccurate manner in which the entries are made, it has been found impossible to classify a number of the substances. Those of unknown or uncertain character have been placed under the head of Miscellaneous.

I. INVERTEBRATA.

Class Protozoa.

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Pori-fera.	Sponge *Spongia officinalis.*	The skeleton		New York	700 lbs.					
				Leghorn			112 lbs.			

Class Insecta.

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Lepidoptera.	Silkworm *Bombyx mori.*	The gut		Messina			1 cwt.		2 cwt.	
					pieces.	pieces.	pieces.	pieces.	pieces.	
		Silk, the fibres of the cocoon.		Bombay	21		10			
				Newfoundland				2		
				Trinidad				2		
				Havanna					2	
					21		10	4	2	
		Silk waste		Italy	6 bales.					
					cwt.	cwt.	cwt.	cwt.	cwt.	
noptera.	The Bee *Apis mellifica.*	The honey		St. Domingo	3					
				Rotterdam	2	18				
				Spain	54				2	
				Montreal	2	1	1		4	
				Jamaica		14	24	48	110	
				Leghorn		14		2		
				Portugal		10	8	15	3	
				Cardenas			1	6	5	
				Hamburg			2	1		
				France				6	90	
				Sicily				4	15	
					61	57	36	82	159	

Hyme[noptera]		The wax		St. Domingo	cwt. 3	cwt. 6	cwt. 3	cwt. 1	cwt.
				Jamaica	2	7	2	6	20
				New York	21	20			
				Philadelphia	....	15			
				Rotterdam	....	2			
				Marseilles	....	7			
				Corsica	....	....	20		
				Morocco	....	....	3	10	
				Hamburg	....	....	3		
					26	57	31	17	20

Class Crustacea.

Deca-poda.	The Lobster *Homarus vulgaris, &c.*	....	....	Miramichi	....	....	....	138 boxes	
				Yarmouth Roads	....	....	....	....	140 boxes

Class Mollusca.

Con-chifera.	The Oyster *Ostrea edulis.*	The animal	....	New York	barrels. 3	barrels. 7	barrels. 3	barrels. 2	
				Montreal	....	....	2		
					3	7	5	2	

II. VERTEBRATA.

Class Pisces.

Malacopterygii subbrachiati.	The Cod *Gadus morrhua.*	The fish salted	Northern Seas	Newfoundland	cwt. 22,214	cwt. 10,838	cwt. 1,723	cwt. 9,866	cwt. 22,154
				Labrador	22,972	15,900	17,672	12,660	21,572
					45,186	26,738	19,395	22,526	43,726
		Sound or air-bladder salted.	....	Newfoundland	....	51 cwt.	23 cwt.	5 cwt.	120 cwt.

VERTEBRATA.—Class Pisces (*continued*).

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Malacopterygii subbrachiati.	Ling........ *Gadus molva.*	The fish salted...	Northern Seas...	Halifax........	....	127 cwt.				
	The Haddock .... *Gadus Æglefinus.*	The fish salted...	Northern Seas...	Nova Scotia......	131 tons.					
		Smoked Haddocks, known as Bervies.	....	Newfoundland...	....	....	....	55 lbs.		
					cwt.	cwt.	cwt.	cwt.	cwt.	
	The Salmon........ *Salmo salar.*	The fish salted...	Northern Seas...	Dalhousie, N. B.	6					
				Newfoundland...	542	125	30	15	220	
				Moulmein	10					
				Quebec........	....	30	25	....	13	
				Miramichi	....	6	2			
				Picton, N. S. ...	....	....	7			
				Bathurst	....	....	5			
				St. John's, N. B.	....	....	....	3	8	
					558	161	69	18	241	
					lbs.	lbs.	lbs.	lbs.	lbs.	
	Capelines .... *Salmo grœnlandicus.*	The fish preserved.	Northern Seas...	New Brunswick..	2,600					
				Labrador	600	3,150	250	....	150	
				Newfoundland...	13,100	10,950	1350	1900	1850	
					16,300	14,100	1600	1900	2000	
					cwt.	cwt.	cwt.	cwt.	cwt.	
abdominales.	The Herring .... *Clupea harengus.*	The fish salted...	Northern Seas...	St. John's, N. B.	1228	913	1569	940	937	
				Halifax........	20	75				
				Newfoundland...	21	23	639	44	130	
				New York	96					
				Quebec........	....	1	7	....	2	
				Labrador	....	....	2	....	7	
				Picton, N. S. ...	....	....	5			
					1365	1012	2222	984	1076	

Malacopterygii		The oil		Newfoundland	50 gall.					
	Sardines *Clupea sardina.*	The fish preserved.		France	cases. 199	cases. 62	cases. 66	cases. 10	cases. 282	
	The Anchovy *Engraulis enchrasicholus.*	The fish preserved.		Italy	lbs. 20	lbs. 84	lbs. 336	lbs.	lbs. 120	
				Sicily	23					
					43	84	336	....	120	
	The Shad *Clupea alosa* (Linn.). *Alosa vulgaris* (Cuv.).	The fish preserved.		Quebec	....	80 lbs.				
				St. John's, N. B.	....	....	....	90 lbs.	60 lbs.	
Acanthopterygii.	The Mackerel *Scomber scombrus.*	The fish preserved.	Temperate and Northern Seas	Halifax	....	46 cwt.				
				Newfoundland	....	....	....	....	4 cwt.	
Chondropterygii. Branchiis liberis.	The Sturgeon *Accipenser sturio.*	Isinglass; the dried air-bladder.		Berbice	3 cwt.					
				Rouen	....	....	....	6 cwt.		

Class Reptilia.

Testudinata.	Turtle (living) *Chelonia mydas, &c.*	The flesh	Tropical Seas	Tobago	3	....	....	....	4	
				Jamaica	....	....	4	13		
				Honduras	....	....	....	....	5	
				Matangas	....	....	....	5		
				Barbadoes	....	....	....	....	2	
					3	....	4	18	11	

VERTEBRATA.—Class Reptilia (*continued*).

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
					lbs.	lbs.	lbs.	lbs.	lbs.	
Testudinata.	Tortoise, Hawk's-bill Turtle. *Chelonia imbricata.*	The carapace; known as Tortoise-shell.	Tropical Seas	St. Domingo	30	20	12	24		
				Mobile		10				
				Corisco Bay				280		
				Jamaica					13	
					30	30	12	304	13	

Class Aves.

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
								dozen.	dozen.	
Gallinaceæ.	Domestic Fowl	The eggs		Lisbon				10		
				Oporto				180	592	
				Morocco					20	
				Bordeaux					30	
								190	642	
Palmipedes.	The Goose *Anser* (sp.?).	The quills		Riga					7 cwt.	
					tons.	tons.	tons.	tons.	tons.	
Natatores.	Penguin *Aptenodytes, &c.*	Guano; excrement of Sea-birds.	Peruvian and African shores	Callao	5000	6660	9360	7540	3860	
				Patagonia	1250					
				Valparaiso	420	233			300	
				New York		80				
				Ichaboe				260		
				Chincha Islands				950	1550	
				Bolivia				1200		
				Bird Island					470	
					6670	6973	9360	9950	6180	

Class Mammalia.

Rodentia.	Chinchilla Skins and Chilian Skins. *Chinchilla lanigera.*	The fur	Chilian and Peruvian Andes.	Callao	....	144			
				Valparaiso	....	100			
				Callao	....	....	....	156	
						244	....	156	
Pachydermata.	The Indian Elephant *Elephas indicus.*	The tusks	India	Moulmein	2	....	....	14	15
				Leghorn	1				
				Port Natal	....	2			
	The African Elephant *Elephas africanus.*	The tusks	Africa	Corisco Bay	....	....	....	4	
					3	2	....	18	15
	The Horse *Equus caballus.*	The hair	....	Archangel	....	....	....	....	120 cwt.
Ruminantia.	The Moose Deer or Elk *Cervus alces.*	Horns	....	Windsor, N. S.	....	....	6		
				St. John's, N. B.	....	....	....	....	2
				New York	....	....	....	2	
	Deer *Cervus* (sp.?).	Horns	....	Quebec	10	12			
				Newfoundland	....	....	8	3	
				St. John's, N. B.	....	....	....	11	
					10	12	8	14	
		Heads	....	Quebec	....	4			
	Reindeer *Cervus tarandus.*	The tongue	North of Europe	Archangel	....	....	....	....	209
	Bullocks and Oxen *Bos taurus.*	....	....	Oporto	....	....	....	35	368
		The tongue	....	Archangel	....	....	....	100	

VERTEBRATA.—Class Mammalia (*continued*).

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Ruminantia.	Bullocks and Oxen .... *Bos taurus.*	The hide	....	New York	597	....	....	1570	6597	
				Newfoundland...	284	65	139	91	399	
				Trinidad	2062	1401	1240	1863	1400	
				St. Vincent	160	190				
				Barbadoes	207					
				St. Domingo ...	23					
				Hamburg	1431	250	638			
				Holland	176					
				Denmark	248					
				France	200					
				Singapore	171	2003	300	600		
				Callao	....	144	....	96		
				Mauritius.........	....	4				
				Jamaica	....	....	178	118	140	
				Sourabaya	....	....	800			
				New Orleans ...	....	....	829	....	849	
				Valparaiso	....	....	....	17		
				Surinam	....	....	....	182	99	
				Morocco	....	....	....	....	117	
				Demerara.........	....	....	....	....	37	
				Archangel	....	....	....	....	100	
				Berbice	....	....	....	....	54	
					5559	4057	4124	4537	9792	
Cetacea.	The Whale .... *Balæna mysticetus.*	Oil. (The return includes also Seal and Cod oil.)	....		tuns.	tuns.	tuns.	tuns.	tuns.	
				Newfoundland...	3425	3020	1806	2264	2871	
				New York	125	205	190	212	140	
				Holland	....	17				
	The Sperm Whale. *Physeter macrocephalus.*			Boston............	9					
				Labrador	21					
					3580	3242	1996	2476	3011	
		Whale-foot, oil and fat.	....	New York	10 tons.	114 tons.	153 tons.	131 tons.	114 tons.	

		Whalebone, or Baleen.		Newfoundland	2 cwt.					
		Whale-oil soap		New York			390 cwt.	20 cwt.		
Carnivora.	Bears (living) *Ursus americanus.*		N. America	Newfoundland		1				
				Montreal			2			
	The Seal *Phoca vitulina*, and various species.	The skin	Arctic Seas	Newfoundland	166,635	123,101	71,557	103,452	112,503	

Animal Substances not distinctly Classified in the Returns.

Animal Charcoal.	Bone-ash			Buenos Ayres					700 tons.	
	Bone-black			Hamburg	10 tons.					
					tons.	tons.	tons.	tons.	tons.	
	Bone-charcoal			Nantes	110		30			
				Rotterdam	15	20			30	
				Antwerp		73	70	80		
				Demerara				53		
					125	93	100	133	30	
	Velvet Powder			Rouen					30 cwt.	Consists of ground wool, and is used by paper designers for giving the rich velvet appearance to flock paper.
					cwt.	cwt.	cwt.	cwt.	cwt.	
	Wool			Spain	36					
				Russia	261					
				Syria	36					
				Bombay	150	465	128	345		
				Melbourne	33	381				
				Mauritius			552		114	
				Morocco			207	396	501	
				Jamaica			8		18	
				Malta				180	504	
				Portugal				71	546	
				Callao					90	
					516	846	895	992	1773	

Animal Substances (continued).

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
					cwt.	cwt.	cwt.	cwt.		
	Pigs' Hair	....	....	New York	1313	897	2010	864		
				Hamburg	834	1026				
				Altona	....	99				
					2147	2022	2010	864		
	Cattle Horns	....	....	St. Domingo ...	1000					
				Singapore	....	1855	5976			
				Jamaica	....	....	215			
				Mauritius........	....	....	....	....	3,825	
				Callao	....	....	....	....	12,000	
				Buenos Ayres ...	....	....	....	....	26,057	
					1000	1855	6191		41,882	
					tons.	tons.	tons.	tons.	tons.	
	Cattle Hoofs and Horn Scraps.	....	....	New York	550	412	159	153	285	
				Boston	7	5				
				Hamburg	10	34	174	27		
				St. Domingo ...	....	1				
				Altona	....	13				
				Montreal	....	4	....	....	18	
				Buenos Ayres ...	....	....	....	....	16	
					567	469	333	180	319	
					tons.	tons.	tons.	tons.	tons.	
	Tallow	Animal fat	....	New York	166	567	98	27	58	
				Boston	....	28				
				Buenos Ayres ...	....	....	....	....	208	
				Melbourne	....	3				
				Leghorn	4	....	2	8		
				St. Petersburg ..	92	....	....	22		
				Cronstadt........	....	....	....	90		
				Archangel	....	....	....	6	4	

				Taganrog	132					
				Kertch			225			
				Prussia			18			
					394	598	343	153	270	
	Tallow Oil			New York			800 gall.			
	Stearine			New York			795 cwt.			
	Gelatine			Rouen				5 cwt.		
	Glue (Glutine)	Hides of various animals.		St. Petersburg	cwt. 700				cwt.	
				Hamburg	70					
				Berbice					28	
					770				28	

B.—VEGETABLE SUBSTANCES.

Thallogens.

	Producing Plant.									
Lichenes.	Orchella-weed *Roccella tinctoria, &c.*	The thallus		Lisbon		252 cwt.	212 cwt.			Used in dyeing.
Fungi.	Mushrooms	Fungus pickled	France	Bordeaux					100 lbs.	

Endogens.

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
[...]naceæ.	Wheat .... *Triticum vulgare.* *T. hybernum.* *T. æstivum*, &c.	The grain.........	*Vide* places of export.		qrs.	qrs.	qrs.	qrs.	qrs.	
				Russia on Black Sea	9,756	7,577	....	4,736	2,380	
				Russia on Baltic Sea.....	460					
				Prussia	1,789	1,480	850	1,500		
				Turkish Dominions	14,461	9,635				
				Danubian Principalities	7,963	900	....	280		
				Syria and Palestine	4,740	800	....	3,300	930	
				Italy...............	4,725	....	2,350	1,036		
				Hanover	1,760	1,245	1,995			
				Oldenburgh	248					
				Denmark	795	280				
				Spain	....	550	8,052			
				France	720	4,291	20,224			
				Portugal	25	....	12			
				Belgium	1,100	....	346			
				Alexandria	62,625	62,096	82,135	49,266	26,748	
				Malta	4,122	....	....	1,600	167	
				Hamburgh	1,487	....	245			
				New York	46,834	29,336	14,568	138,904	96,284	
				Montreal	10,340	3,730	1,450	41,140	41,205	
				Quebec............	1,933					
				Philadelphia ...	....	4,081				
				Asia Minor	....	2,750	2,806			
				Trieste	....	....	1,975	1,024		
				Morocco	....	....	8			
				Greece	....	....	....	2,490		
				Savannah.........	....	....	....	80		
					175,883	128,751	137,016	245,356	167,714	

Grami…	Flour, the ground grain	....	New York	tons. 9,993	tons. 4,568	tons. 1,344	tons. 12,081	tons. 8,288
			Montreal	4,747	1,478	306	3,218	2,852
			Quebec	474	....	....	31	
			United States	1,517	658	1	255	644
			Newfoundland	13	....	....	....	39
			Melbourne	9	190			
			St. Domingo	99				
			Alexandria	313				
			France	3,156	316			
			Italy	320				
			Hamburg	6	47			
			Denmark	....	41			
			Spain	....	306	1,080	518	
			Demerara	....	....	4		
				20,647	7,604	2,735	16,098	11,823
	Semolina, a preparation of wheat.	....	Spain	cwt. 30	cwt.	cwt. 45	cwt. 23	cwt. 15
			France	1	....	18	....	2
			Leghorn	....	....	....	1	
				31	....	63	24	17
	Maccaroni and Vermicelli; Wheaten Paste.	....	Bordeaux	cwt. 150	cwt. 109	cwt. 40	cwt.	cwt. 119
			Leghorn	1	1	....	190	2
			Sicily	1	....	....	....	1
			Naples	....	....	....	....	10
				152	110	40	190	132
Barley *Hordeum distichum.* *H. vulgare.*	The grain	*Vide* places of export.	Malta	qrs. 7,822	qrs.	qrs. 3,890	qrs.	qrs.
			Spain	2,100				
			Danubian Principalities	750	....	....	1,350	
			Cyprus	1,000	1,000	2,068		
			European Turkey	7,543	5,270	....	11,639	

Endogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
					qrs.	qrs.	qrs.	qrs.	qrs.	
	Barley (*continued*)	....	....	Alexandria	2,696	....	....	2,700	10,973	
				Algeria........	950	650				
				Hanover	304					
				Murcia........	....	1,200				
				Syria	....	1,300	....	....	2,900	
				Denmark	....	300				
				Smyrna	....	1,200				
				Tarsus	....	....	1,968			
				Hamburg	....	....	31			
				Russia on Black Sea........	....	....	....	7,800		
				Trieste	....	....	....	....	1,400	
				Scala Nova	....	....	....	....	1,800	
					23,165	10,920	7,957	23,489	17,073	
					qrs.	qrs.	qrs.	qrs.	qrs.	
	Rye .... *Secale cereale.*	The grain........	....	Rodosto	1500					
				Constantinople...	1100					
				Odessa	3966					
				New York	....	52	....	....	3003	
				Montreal	....	....	....	362		
					6566	52	....	362	3003	
	Dari-seed, Darra, Durra, or Doura. *Andropogon Sorghum.*	Seed employed as food.	....	Malta	....	7920 bush				
	Rice .... *Oryza sativa.*	Paddy, rice in the husk.	The Tropics......	Singapore	....	480 cwt.				
					tons.	tons.	tons.	tons.	tons.	
				New York	220	33	40	267	148	
naceæ.				United States ...	1	....	2	24	2	
				Halifax........	1					

			Holland	7				
			Calcutta	128	....	....	687	
			Melbourne	25				
			Singapore	....	20			
			Bombay	....	....	30		
			Mauritius	....	....	5		
				382	53	77	988	150
				qrs.	qrs.	qrs.	qrs.	qrs.
Corn (Not distinguished.)	....	....	New York	399	29,346	12,058	10,974	4,575
			Montreal	....	....	10		
			New Orleans	....	....	200	3,355	
				399	29,346	12,268	14,329	4,575
				qrs.	qrs.	qrs.	qrs.	qrs.
Indian Corn, Maize *Zea Mays.*	....	America, Asia, Southern Europe	Salonica	1721				
			Danubian Principalities	2840	....	....	2,693	2,850
			Turkey on Black Sea	1739	....	....	4,020	2,400
			New York	2275	11,557	11,596	7,803	5,787
			St. John's, N. B.	25				
			Philadelphia	....	3,588			
			Alexandria	....	240			
			Montreal	....	5,769	....	1,312	
			Greece	....	....	1,350	3,940	
			Trieste	....	....	400		
			New Orleans	....	....	....	1,053	
			Baltimore	....	....	....	1,825	
			Morocco	....	....	....	1,325	
			Odessa	....	....	....	....	1,780
				8600	21,154	13,346	23,971	12,817
				lbs.	lbs.	lbs.	lbs.	lbs.
	Hominy, preparation of Maize.	....	New York	30	150	290	300	40
			New Orleans	....	....	....	80	
				30	150	290	380	40

Grand

Endogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
	Timothy Grass……… *Phleum pratense.*	The seed ………	………	New York ……	………	20 bshls.	………	………	215 bshls.	
					bushels.	bushels.	bushels.	bushels.	bushels.	
	Canary-seed……… *Phalaris canariensis.*	Seed employed to feed birds.	………	Rotterdam ……	1749					
				Sicily ………	………	120	1758	2730	1107	
				Spain ………	………	………	………	261		
				France ………	………	………	………	………	2310	
					1749	120	1758	2991	3417	
					bushels.	bushels.	bushels.	bushels.	bushels.	
	Italian Rye-grass seed …… *Lolium italicum.*	The seed ………	………	Leghorn ………	560	………	2100	9100	9,646	
				France ………	………	………	………	………	2,800	
				Trieste………	………	………	………	………	280	
					560	………	2100	9100	12,726	
	Grass-seed ………	The seed ………	………	Montreal ………	………	………	………	………	800 bshls.	
					tons.	tons.	tons.	tons.	tons.	
	Sugar Cane……… *Saccharum officinarum.*	The crystallized juice.	………	Antigua ………	………	341	126	118	………	About 2000 tons of Beet-root Sugar imported in 1858. *Beta vulgaris*; Nat. Or. *Chenopodiaceæ.* Small quantities of Maple Sugar are occasionally received (in presents) from Canada and the States. *Acer saccharinum*; Nat. Or. *Aceraceæ.* Sugar produced by the Date Palm is also imported, but not generally distinguished from Cane Sugar. *Phœnix sylvestris.*
				Barbadoes ……	6	………	5	1	10	
				Grenada ………	832	510	640	337	760	
				Jamaica ………	885	1,350	1,041	933	1,047	
				Montserrat ……	………	………	5	………	………	
				St. Kitts ………	519	1,224	1,015	340	364	
				St. Vincent ……	340	357	74	127		
				Tobago………	311	199	165	123	160	
				Trinidad ………	10,909	13,285	10,891	11,910	9,303	
				Demerara………	1,906	4,729	4,320	3,590	5,721	
				Berbice ………	70	340	140	212	168	
				Surinam ………	468	928	1 633	934	933	
				Halifax ………	9					
				Porto Rico ……	91	1,752	229			
				Cuba ………	5,616	5,385	3,170	1,498	3,002	
naceæ.				Newfoundland….	159	48	65	………	167	

Grami				Brazil	3,790	2,980	3,250	582	3,604
				Mauritius.........	9,676	13,370	10,708	10,031	7,409
				Batavia	....	214	419	....	1,925
				Manilla	....	630	1,147	....	2,159
				Sourabaya	....	1,364	719		
				New Orleans ...	....	2			
				France	....	....	668	260	
				St. John's, N. B.	....	....	....	31	
				Calcutta	....	....	....	1	
				Singapore	....	....	....	44	
				New York	....	....	....	....	257
					35,587	49,008	40,430	31,072	36,989
					tons.	tons.	tons.	tons.	tons.
		Molasses, uncrystallizable portion of the juice.	....	Antigua	....	345	63	69	
				Barbadoes	3,174	2,385	1,430	1,601	754
				Grenada	1	1	10	....	65
				Jamaica	....	....	....	13	12
				St. Kitts	275	258	142	100	56
				St. Vincent	284	407	....	24	
				Tobago............	70	18	....	54	58
				Trinidad	5,516	4,058	2,501	3,157	2,791
				Demerara.........	2,692	1,511	427	834	462
				Berbice	263	112	79	93	149
				Surinam	63	215	74	10	80
				Halifax............	303	41			
				Porto Rico	1,009	1,236	474		
				Cuba...............	10,067	14,220	14,181	16,714	9,893
				Newfoundland...	169	50	638	159	124
				Charleston	....	219			
				France...	....	....	317		
				Windsor, N. S...	....	....	16		
				St. John's, N. B.	....	....	....	114	
					23,886	25,076	20,352	22,962	14,444
	Bamboo .... *Bambusa arundinacea.*	The stem.........	....	St. Domingo ...	20	250			

Endogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Palms.	The Cocoa-nut Palm *Cocos nucifera.*	The nuts	West Indies, &c.	Trinidad	550	1,500	102	3,100	4,100	
				Tobago	5,000	5,000	4,000	2,600	5,700	
				St. Vincent	150			110		
				Honduras	2,300	17,805	42,546	30,600	19,380	
				Porto Rico	150					
				Berbice	2,000				900	
				Demerara	7,068	2,924	8,200	17,250	12,600	
				St. Domingo		5,090				
				Jamaica		2,310	2,000	18,336	22,200	
				Manilla			3,400			
				Grenada				300	2,623	
				Brazil					256	
					17,218	34,629	60,248	72,286	67,753	
		Coir yarn, fibre of covering of fruit.		Bombay		143 cwt.	182 cwt.	13 cwt.	220 cwt.	
		Coir rope		Bombay			86 cwt.			
	The Date Palm *Phœnix dactylifera.*	The fruit or date		Lisbon		182 lbs.		20 lbs.		
	The Piassava Palm *Attalea funifera.*	Dilated base of the petiole.	Brazil	Bahia	70 tons.	20 tons.	48 tons.	22 tons.	52 tons.	Used for brushes, brooms, &c.
	The Cohune Palm *Attalea Cohune*	Cohune or Cahoun nuts yield oil in quantity.		Belize			12 tons.			
	The Rattan Palm *Calamus rotang.* *C. rudentum,* &c.	The climbing stem.		Singapore		cwt. 17	cwt. 56	cwt.	cwt.	Used for chair-bottoms, whips, &c.
				Java		67	65			
				Batavia		11	10		90	
						95	131		90	

	Cane Reeds .... (Not specified.)	The stem	....	Berbice	10,000	....	....	....	....	They grow in swamps, are about 1¼ inch in diameter at the base, and taper towards the top. Their colour is generally yellow. When brought home, they are prepared for weaving purposes. For coarse weaving a part is used here, and the rest exported to Canada. Sometimes they are used for fishing-rods.
				Spain	60					
				Savannah	....	19,400	12,600	5000	17,540	
					10,060	19,400	12,600	5000	17,540	
					cwt.	cwt.	cwt.	cwt.	cwt.	
	The Sago Palms .... *Sagus Rumphii*, and other Palms.	Pearl sago, the granulated starch.	....	Singapore	1152	2025	2995			
				Mauritius	6					
				Batavia	....	....	....	....	6	
					1158	2025	2995		6	
		Sago flour	....	Singapore	930 tons.	1083 tons.	504 tons.	778 tons.		
Naiadaceæ.	Sea Grass .... *Zostera marina.*	The leaves	....	Hamburg	....	15 cwt.	64 cwt.	....	....	Used in stuffing cushions, &c.
Bromeliaceæ.	Pine Apple .... *Ananas sativa.*	The fruit	....	Jamaica	....	....	10			
				New York	....	....	....	18		
Iridaceæ.	Orris .... *Iris florentina.*	Rhizome of Florence Iris.	....	Leghorn	3 cwt.	....	....	....	4 cwt.	Used by druggists as a perfume, &c.
Musaceæ.	The Plantain and Banana ... *Musa paradisiaca*, the Plantain. *M. sapientum*, the Banana. *M. textilis*, produces Manilla Hemp.	The fibre	....	Jamaica	....	6 cwt.				
Zingiberaceæ.	Ginger .... *Zingiber officinale.*	The preserved rhizome.	E. Indies, China, W. Indies, Africa	Jamaica	100 cwt.	174 cwt.	147 cwt.	88 cwt.	78 cwt.	

Endogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Marantaceæ.					lbs.	lbs.	lbs.	lbs.	lbs.	
	Arrowroot .... *Maranta arundinacea.*	Rhizome	....	Grenada	224	28	2,800	....	392	
				Barbadoes	336	28	476	5,768		
				Trinidad	20,160	28	28	30,184	1,456	
				Tobago.........	112	....	....	28		
				Jamaica	3,024	588	1,092	3,192	1,344	
				St. Vincent	28,894	212,688	48,972	16,856		
				St. Kitts	2,016	672	140	616	3,388	
				Berbice	224	672	....	56		
				Demerara	15,904	12	56	1,596	6,776	
				Surinam	224	....	140	....	1,708	
				New York	4,032					
				Antigua	....	2,128	....	560		
				Port Natal	....	5				
				Montserrat	....	....	812			
				Mauritius.........	....	....	56			
				Havanna	....	....	....	28		
				Brazil	....	....	....	168		
				Marseilles	....	....	....	84		
					75,152	216,849	54,572	59,136	15,064	
					lbs.	lbs.	lbs.	lbs.	lbs.	
	Tous-les-mois .... *Canna Indica.*	....	....	Grenada	28	28	....	....	56	
				Barbadoes	28					
				St. Kitts	2464	8904	....	130		
				Antigua	....	50	....	140		
				Trinidad	....	224				
					2520	9206	....	270	56	
Liliaceæ.					bushels.	bushels.	bushels.	bushels.	bushels.	
	The Onion .... *Allium cepa.*	The bulb	See places of export.	Portugal	237	245	2353	1497	1825	
				Rotterdam	685	447				
				Spain	....	12	4	25		
				France	....	60	....	....	1960	
				Quebec.........	....	12	3	....	13	
					922	776	2360	1522	3798	

		The seed	....	Rotterdam	36 bush.					
				Bordeaux........	....	....	....	....	6 bushels.	
	Garlic .... *Allium sativum.*	The bulbs........	....	Cadiz	....	....	....	100 lbs.		
	Gourds Aloes .... *Aloe spicata.* *A. vulgaris.* *A. socotrina.* *A. indica.* *A. purpurascens.*	Inspissated juice	....	Barbadoes	15	....	....	....	....	Imported in shell of the gourd.
					cwt.	cwt.	cwt.	cwt.	cwt.	
Dioscoreaceæ.	Yams .... *Dioscorea sativa.* *D. alata.* *D. aculeata.*	....	Tropical countries.	Barbadoes	3					
				Jamaica	3	12	12	9	10	
				St. Kitts	....	....	9			
				Richmond	....	....	3			
				Mobile	....	....	....	3		
				Demerara........	....	....	....	....	3	
					6	12	24	12	13	
						lbs.	lbs.	lbs.	lbs.	
Smilaceæ.	Sarsaparilla .... *Smilax officinalis.*	The root	....	New York	....	200	....	....	100	
				Jamaica	....	....	....	....	200	
				Honduras........	....	....	....	....	4600	
						200			4900	
				Exogens.						
					logs.	logs.	logs.	logs.	logs.	
Coniferæ.	Pine .... *Pinus strobus.* *P. palustris, &c.*	The timber	North America...	New Brunswick..	14,947	24,160	14,902	26,434	23,354	1*s.* 2*d.* per cubic foot.
				Nova Scotia......	555	1,193	944	4,022	2,119	
				Quebec............	44,559	53,731	38,603	43,225	64,368	
				New Carlisle ...	1,914					
				Gaspe	....	980	....	....	159	
				Newfoundland...	....	224				
				Newcastle	....	....	....	2,214	1,256	
					61,975	80,288	54,449	75,895	91,256	

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
					deals.	deals.	deals.	deals.	deals.	
	Pine Deals	....	....	Montreal	8,839	5,693	6,000	7,800	13,020	10*d.* per cubic foot.
				Quebec........	41,281	33,591	39,400	40,900	184,274	
				St. John's, N. B.	80,140	91,000	92,500	85,400	170,000	
				Gaspe	....	2,071	4,500	3,600	9,440	
				Memel	....	550				
				Nova Scotia........	....	3,552	4,300	4,900	6,000	
					130,260	136,457	146,700	142,600	382,734	
	Pitch Pine .... *Pinus rigida.*	....	....	Savannah	441 logs.	727 logs.	1244 logs.	771 logs.	3509 logs.	1*s.* 6*d.* per cubic foot.
				Savannah	....	....	....	....	399 deals	
					logs.	logs.	logs.	logs.	logs.	
	Red Pine	....	....	Quebec........	7,100	4,843	3,624	10,377	11,147	1*s.* 6*d.* per cubic foot.
	Pine and Spruce (Pickets)........	....	....	St. John's, N.B., & Windsor, U.S.	60,000	65,000	59,000	70,000	110,000	£2 10*s.* per 1000.
	Fir	....	....	Dantzic	....	....	574 logs	....	....	1*s.* per cubic foot.
				Memel	....	....	....	....	456 logs.	
					logs.	logs.	logs.	logs.	logs.	
	Hemlock (Spruce) .... *Abies canadensis.*	The timber	N. America	Picton, U. S.	88	19	217	403	314	9*d.* per cubic foot.
				Maitland, U. S........	....	27				
					88	46	217	403	314	
	Tamarack or Hackmatack .... *Larix americana.*	The timber	....	Quebec........	....	404 logs.	375 logs.	....	601 logs.	1*s.* per cubic foot.
				Quebec........	....	....	....	....	4600 sleepers.	
					deals and battens, pieces.	deals and battens, pieces.	deals and battens, pieces.	deals and battens, pieces.	deals and battens, pieces.	
	Spruce .... *Abies alba.*	The timber	....	New Brunswick........	200,000	200,350	199,000	200,080	350,000	10*d.* per cubic foot.
				Quebec........	99,800	100,400	100,500	100,110	190,000	
				Nova Scotia........	100,200	100,000	100,450	99,950	195,000	
feræ.					400,000	400,750	399,950	400,140	735,000	

Conif. { Bass Wood	The timber		Quebec	24 logs	20 logs	20 logs	....	6 logs	1*s.* per cubic foot. Rarely imported.
Pencil Cedar *Juniperus Bermudiana.*	The timber		New Orleans	....	....	....	....	630 logs	
				tons.	tons.	tons.	tons.	tons.	
Rosin	Obtained by distilling off oil of turpentine from turpentine balsam, yielded by varieties of Pine.		New York	5099	5004	5060	4958	5228	
			Wilmington	143	....	36			
			Hamburg	95					
			Boston	....	14				
			Mobile	....	12				
			Charleston	....	....	25	60	117	
			Montreal	....	....	....	....	124	
				5337	5030	5121	5018	5469	
Gum Dammar *Dammara orientalis.*	The resin		Batavia	....	114 cwt.				
				barrels.	barrels.	barrels.	barrels.	barrels.	
Tar Product of Coniferous trees.			New York	3,650	16,015	18,715	3,903	9,105	
			Wilmington	500					
			Archangel	14,301	4,078	....	19,562	14,398	
			Hamburg	....	500	910			
			Newfoundland	....	....	73			
				18,451	20,593	19,698	23,465	23,503	
				cwt.	cwt.	cwt.	cwt.	cwt.	
Turpentine Product of Coniferous trees.			New York	1728	6692	7948	3320	3936	
			France	....	....	....	....	200	
			Charleston	....	....	....	....	144	
				1728	6692	7948	3320	4280	
				cwt.	cwt.	cwt.	cwt.	cwt.	
Pitch	Produced by heating resin with water to dryness.		Archangel	960	631	....	1967	1372	
			New York	....	....	....	637		
			Trinidad	....	....	....	....	4000	
				960	631	....	2604	5372	

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Coniferæ.	The Juniper *Juniperus communis.*	The berries	....	Rotterdam	5 cwt.					
				Leghorn	....	....	4 cwt.	330 cwt.		
Scepaceæ.	Cocus or Kokra Wood *Lepidostachys Roxburghii.*	The timber	....	Jamaica	....	14 tons.	....	....	....	Used for making knife-handles, &c.
Artocarpaceæ. Suborder Moreæ.	The Fig *Ficus carica.*	The preserved fruit.	Europe and Asia.		cwt.	cwt.	cwt.	cwt.	cwt.	
				Spain	230	493	439	1532	728	
				Portugal	1	5	1	10	12	
				Smyrna	210	....	4			
				Sicily	....	1				
				St. Michaels	....	....	....	....	1	
				Trieste	....	....	....	....	6	
					441	499	444	1542	747	
		Fig Cake, Figs and Almonds.	....	Spain	17 cwt.	....	732 cwt.	899 cwt.	158 cwt.	
		The living tree	....	New York	1					
	Fustic *Maclura tinctoria.*	The wood	West Indies and South America.		tons.	tons.	tons.	tons.	tons.	Employed in dyeing.
				New York	225	172	199	80	60	
				Jamaica	21	43	8	105	83	
				Alexandria	5					
				Cuba	....	20	....	50	20	
					251	235	207	235	163	
Cannabineæ.	The Hop *Humulus Lupulus.*	Resinous scales surrounding the fruit.	....		cwt.	cwt.	cwt.	cwt.		
				New York	....	176	894	4		
				Rotterdam	....	4				
						180	894	4		
	Hemp *Cannabis sativa.*	The fibre	....		tons.	tons.	tons.	tons.	tons.	
				Bombay	6	23	....	14		
				Malta	20					

Suborder										
Urticaceæ.				Russia on Baltic	409	....	....	126	627	
				Italy	75	205	24	....	94	
				Prussia	....	307	29			
				New York	....	18				
				Manilla	....	161	420	....	400	
				Morocco	....	....	....	10		
				Trieste	....	....	....	44	74	
					510	714	473	194	1195	
					bushels.	bushels.	bushels.	bushels.	bushels.	
		The seed	....	Riga	120	....	....	....	405	
				Rotterdam	1792	468				
				Smyrna	320					
				Sicily	....	....	228	340	1544	
				Naples	....	....	4			
					2232	468	232	340	1949	
					pieces.	pieces.	pieces.	pieces.	pieces.	
Ulmaceæ.	The Elm *Ulmus americana.*	The timber	....	Quebec	2331	5235	4046	4335	5194	1*s*. 8*d*. per cubic foot.
					cwt.	cwt.	cwt.	cwt.	cwt.	
Salicaceæ.	Willows *Salix* (sp. ?).	....	....	Hamburg	7	2	....	2		
				Charente	1					
				Altona	....	1				
					8	3	....	2		
					logs.	logs.	logs.	logs.	logs.	
Betulaceæ.	The Birch *Betula* (sp. ?).	The timber	....	New Brunswick	334	1986	679	1659	2028	1*s*. 4*d*. per cubic foot.
				Nova Scotia	2453	2810	2960	1929	3266	
				Quebec	332	235	293	221	1200	
				Gaspe	....	131	16	....	30	
				New Carlisle	....	....	....	....	209	
				Prince Edward's Isle	....	220				
				United States	....	....	....	72		
					3119	5382	3948	3881	6733	

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Betulaceæ.	The Birch (*continued*).	...	...		deals.	deals.	deals.	deals.		
				New Richmond...	277	...	...	101		
				Londonderry, U.S	...	...	3850			
				Picton, U. S.	...	...	700			
					277	...	4550	101		
Euphorbiaceæ.					lbs.	lbs.	lbs.	lbs.	lbs.	
	Cassaripe or Casserepo ...... *Manihot utilissima* (Pohl.). *Jatropha Manihot* (Lin.).	Juice of the root.	...	Demerara	308	56	190	100	200	Used for seasoning soup. The originally poisonous juice is rendered innocuous by being cooked along with meat.
				Trinidad	...	28	87			
				Jamaica	...	...	80			
					308	84	357	100	200	
					cwt.	cwt.	cwt.	cwt.	cwt.	
	Tapioca, Cassava, Jatropha Manihot. Produce of *Jatropha Manihot* (Lin.), or *Manihot utilissima* (Pohl.).	Starch of the root	...	Bahia	2	1	...	1		
				Jamaica	...	1	...	10	1	
				St. Vincent	1	...	...	1		
				Grenada	...	...	...	2	3	
				Demerara........	...	...	4	2		
					3	2	4	16	4	
						cwt.	cwt.	cwt.	cwt.	
	India-rubber .... *Siphonia elastica.* (Also yielded by *Urostigma elastica*; Nat. Ord. *Artocarpaceæ.*)	The milky juice hardened.	...	Sourabaya	...	59	...	...	...	Considerable importations of manufactured India-rubber from New York are not included.
				Corisco Bay	...	...	100	10		
				New York........	...	...	...	210	1090	
						59	100	220	1090	
	Castor Oil .... *Ricinus communis,* or *Palma Christi.*	Oil expressed from seed.	...	Calcutta	...	...	...	12 cwt.	...	Used in machinery as well as medicine.
	Boxwood .... *Buxus sempervirens.* *B. balearica.*	The timber	...	Smyrna	85 tons.	83 tons.				

Corylaceæ.	The Oak *Quercus alba.* *Q. pedunculata.* *Q. sessiliflora.*			Quebec	logs. 1521	logs. 3617	logs. 3358	logs. 2022	logs. 4093	2*s.* per cubic foot.
				Stettin		410				
				Dantzic			101			
				Memel					204	
					1521	4027	3459	2022	4297	
		The seed, acorns.		Seville					6 bushels.	
		The bark, used in tanning.			tons.	tons.	tons.	tons.	tons.	
				France	85					
				Belgium	32	32	45	55	89	
				Italy	21					
				Denmark	26	62				
				Hamburg	192	168	37			
					356	262	82	55	89	
	Valonia *Quercus Ægilops.*	United bracts, forming the cupula of the acorn.	Levant	Smyrna	167 tons.	50 tons.	60 tons.		106 tons	Used in tanning.
	Gall-nuts *Quercus infectorius.*	Excrescences caused by an insect puncture, chiefly used in making writing-ink.			cwt.	cwt.	cwt.	cwt.	cwt.	
				Bombay	692		1250			
				Marseilles			187		242	
				Naples			95			
				Aleppo					288	
					692		1532		530	
	Quercitron Bark *Quercus tinctoria.*	Bark, yields a yellow dye.			cwt.	cwt.	cwt.	cwt.	cwt.	
				New York	1447	538	1187	398	150	
				Baltimore	508					
					1955	538	1187	398	150	
	Live Oak *Quercus virens.*	The timber		Mississippi River.			super. ft. 186,000			2*s.* 4*d.* per cubic foot.
	Corkwood *Quercus Suber.*	Outer layer of bark.	Spain and Portugal principally		tons.	tons.	tons.	tons.	tons.	An importation of 2 cork plants from Oporto in 1857.
				Portugal	243	261	203	345	447	
				Sicily	3	1	9	7	4	
				Spain		8	6	16	2	
					246	270	218	368	453	

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Corylaceæ.					bushels.	bushels.	bushels.	bushels.	bushels.	
	Chestnut	The nut	......	Oporto	......	......	......	......	18	
	Castanea vulgaris or *vesca*.			Lisbon	......	......	......	......	141	
				Bordeaux	......	......	......	......	8	
				Seville	......	......	......	......	15	
				Leghorn	......	......	......	......	108	
				Rouen	......	......	4			
							4		290	
					bushels.	bushels.	bushels.	bushels.	bushels.	
	The Hazel. Filberts, Hazel nuts.	The nut	......	Palermo	......	......	......	......	423	
				Naples	1000	......	......	......	804	
	Corylus Avellana.			Sicily	800	1300	2528	1600	5639	
					1800	1300	2528	1600	6866	
					bushels.	bushels.	bushels.	bushels.	bushels.	
	Nuts	......	......	Sicily	......	4600				
	(Not specified, but probably			St. John's, N. B.	......	......	......	10		
	as above.)			Keresoun	......	......	......	6500		
						4600	......	6510		
Juglandaceæ.	Hickory	The timber	N. America	Quebec	36 logs.	16 logs.	......	......	......	1*s*. 6*d*. per cubic foot. 15 Hickory plants imported in 1854 from New York.
	Carya alba.									
					handspikes and billets.					
				Quebec	1000	......	100	......	......	3*s*. per billet.
				Montreal	......	483				
	Walnut Wood	The timber	America and Continent of Europe.	Quebec	33 tons.	......	......	......	16 tons.	
	Juglans regia.			Italy	......	34 tons.				
	J. nigra.									
					bushels.	bushels.	bushels.	bushels.	bushels.	
	Walnut	The nuts	......	Naples	300	250	542	450	1242	
	Juglans regia.			Bordeaux	50	75	......	......	762	

				Marseilles	....	....	112	....	95	
				Sicily	....	....	10	....	187	
				Morocco	....	....	145	96		
					350	325	809	546	2286	
					lbs.	lbs.	lbs.	lbs.		
Myristicaceæ.	The Nutmeg *Myristica moschata.*	The nuts	Moluccas, West Indies.	Grenada	350	1150				
				St. Vincent	50	50	....	50		
				Melbourne	....	300				
				Singapore	....	....	150			
				Trinidad	....	....	....	50		
					400	1500	150	100		
		Mace, the Arillus	Moluccas, West Indies.	Java	....	140 lbs.				
				Singapore	....	....	180 lbs.			
				Calcutta	....	....	....	70 lbs.		
Menispermaceæ.	Cocculus Indicus *Anamirta paniculata.*	Fruit used by druggists and brewers.	....	Bombay	....	....	52 cwt.			
Cucurbitaceæ.	The Melon *Cucumis Melo.*	....	*Vide* places of export.	Malaga	40	....	48	100		
				Xabea	....	100				
				St. Malo	....	18				
				Oporto	....	....	....	45	24	
				Lisbon	....	....	....	....	100	
					40	118	48	145	124	
					cwt.	cwt.	cwt.	cwt.	cwt.	
Flacourtiaceæ.	Arnotto (Flag), Roll Arnotto *Bixa orellana.*	Pulp surrounding seed.	....	Bordeaux	....	....	18	18	30	Used in dyeing, also in colouring cheese.
				Marseilles	....	....	....	21	90	
				Surinam	....	....	....	....	93	
							18	39	213	
Cruciferæ.	Rapeseed *Brassica Napus.*	The seed	....	Bombay	....	....	50 bahls.	....	500 bahls.	
		The oil-cake	....	Hamburg	180 cwt.	....	22 cwt.			

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Cruciferæ.	Mustard Seed ...... *Sinapis nigra.* *S. alba.*	Seeds used for preparation of table mustard and oil.	......	Bordeaux......	......	......	......	......	1 bshl.	
		Sursey seed	......	Bombay	......	120 bshls.	......	......	48 bshls.	
	Mustard ...... *Sinapis nigra.* *S. alba.*	......	......	Bordeaux......	17 cwt.					
					tuns.	tuns.				
	Rape Oil ...... *Brassica Napus.*	Oil expressed from seed.	......	Hamburg	5					
				Rotterdam	......	151				
				Amsterdam	......	7				
					5	158				
	Radish Seed ...... *Raphanus sativus?.*	The seed	......	Bombay	......	......	......	......	204 bshls.	
Capparidaceæ.	Capers ...... *Capparis spinosa.*	The flower-buds pickled.	......	Seville	......	......	......	150 lbs.		
Byttneriaceæ.					cwt.	cwt.	cwt.	cwt.		
	Cocoa ...... *Theobroma Cacao.*	The seeds......	West Indies...... (*Cacao.*)	Trinidad	50	......	115	250		
				St. Domingo ...	205	......	22			
					255	......	137	250		
					lbs.	lbs.	lbs.	lbs.	lbs.	
		Chocolate, expressed juice of the seeds.	West Indies......	Trinidad	120	......	180	......	10	
				Cadiz	......	10				
				Seville	......	......	......	......	15	
					120	10	180	......	25	

Malvaceæ.	Cotton. *Gossypium herbaceum*, and other species.	The hairs which cover the seeds.	India, Egypt, U. States, West Indies.	Alexandria	tons. 115	tons. 308	tons. 385	tons. 762	tons. 547	
				Bombay	2,685	2,318	2,792	2,481	1,539	
				New York	1,523	1,350	496	370	325	
				Surinam	572	14	40	15	5	
				St. Domingo	20	13				
				St. Vincent	3					
				Demerara	2					
				Trinidad	1	......	......	25	46	
				United States	9,774	5,140	2,579	9,389	5,175	
				Grenada	......	2	11			
				France	......	......	66			
				Cuba	......	......	......	18		
				Mauritius	......	......	......	......	44	
					14,695	9,145	6,369	13,060	7,681	
		The seeds		Grenada	cwt. 2	cwt.	cwt. 25	cwt.	cwt.	
				Mobile	12					
				Surinam	......	......	......	198		
				New York	......	......	......	......	8	
					14	......	25	198	8	
Tiliaceæ.	Jute. *Corchorus capsularis.*	The fibre	India	New York	......	504 tons.				
				Calcutta	......	......	......	220 tons.	98 tons.	Used principally for bagging.
Aceraceæ.	The Maple. *Acer saccharinum.*	The timber	N. America	Quebec	logs. 10	logs. 6	logs.	logs.	logs. 8	1*s.* 3*d.* per cubic foot.
				Montreal	......	......	......	......	16	
					10	6			24	
		Variety named Bird's-eye Maple	N. America	New York	......	......	......	197 plks.	......	6*d.* per superficial foot.
		Maple sugar, the saccharine juice crystallized.		Montreal	cwt. 3	cwt. 2	cwt. 2	cwt.	cwt.	
				Quebec	4	1	4	......	12	
				Halifax	......	1				
				Dalhousie	......	......	......	2		
					7	4	6	2	12	

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Ternstrœmiaceæ.	Tea	The leaves	China.							
	Thea Bohea.									
	T. viridis.				lbs.	lbs.	lbs.	lbs.	lbs.	
	Imperial			Canton	1,456					
	Gunpowder			Canton	9,122	10,370				
				Shanghai	3,762					
				Foochowfoo	....	....	1,320			
	Scented Orange Pekoe			Canton	23,034	30,599				
	Young Hyson			Shanghai	2,027					
				Singapore	....	333				
				Foochowfoo	....	....	3,090			
	Hyson			Shanghai	934					
	Hyson skin			Singapore	....	573				
	Souchong			Singapore	....	282				
				Foochowfoo	....	....	....	17,154		
	Congou			Canton	812,908	781,002				
				Shanghai	450,260	....	280,094	617,190	226,400	
				Foochowfoo	....	....	809,608	1,171,898		
					1,303,503	822,159	1,094,112	1,806,242	226,400	
					tons.	tons.	tons.	tons.	tons.	
Anonaceæ.	Lancewood Spars	The timber	Jamaica, Cuba, &c.	Jamaica	27	50	29	28	89	Used principally for the shafts of carriages.
	Duguetia quitarensis.			Cuba	....	....	....	....	30	
				Berbice	....	....	....	....	1	
				Demerara	....	....	....	....	5	
					27	50	29	28	125	
Ranunculaceæ.	Hellebore	The root and rhizome.		Hamburg	12 cwt.	....	6 cwt.			
	Helleborus officinalis.									
	H. niger, &c.				cwt.	cwt.	cwt.	cwt.	cwt.	
	The Vine	Raisins, dried grapes.		Malaga	9,728	7,133	8,514	12,352	8,830	
	Vitis vinifera.			Smyrna	21	....	1			
				Alicomte	....	....	975			

				Xabea				941	
				Sicily				2	
				Portugal					1
				Venice					5,566
				Montreal					99
					9,749	7,133	9,490	13,295	14,496
					cwt.	cwt.	cwt.	cwt.	cwt.
Vitaceæ.		Currants, dried seedless Corinthian grape.		Leghorn	7				
				Wallachia	49				
				Greece				1098	
				Sicily				450	240
				Trieste					453
					56			1548	693
					cwt.	cwt.	cwt.	cwt.	cwt.
		Ripe grapes		Malaga	568	260	317	399	269
				Portugal	2				7
				Bordeaux				1	1
				New York					1
					570	260	317	400	278
Aurantiaceæ.	The Lemon *Citrus Limonum.*	The fruit		Spain	bushels.	bushels.	bushels.	bushels.	bushels.
				Sicily	238	313	604	987	622
				Portugal	687	78	151	1329	3982
								4	36
					925	391	755	2320	4640
		The juice	Sicily	Sicily	46 tuns.	44 tuns.	17 tuns.	45 tuns.	69 tuns.
					cwt.	cwt.	cwt.	cwt.	
		The essence		Sicily	8		2	1	
				Leghorn	3	1		1	
					11	1	2	2	
		The essential oil			15 galls.	16 galls.		45 galls.	
		The peel or rind preserved.		Messina	30 cwt.	185 cwt.	50 cwt.	40 cwt.	235 cwt.

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Aurantiaceæ.							cwt.	cwt.	cwt.	
	The Lime *Citrus Limetta.*	The fruit	West Indies	Trinidad			1	9	2	
				Jamaica			2			
				Demerara				1	3	
				Grenada					1	
							3	10	6	
					tuns.	tuns.	tuns.	tuns.	tuns.	
		The juice		Jamaica	1	2	9	6	4	
				Messina			2	4		
				Marseilles				1		
				Valentia					2	
					1	2	11	11	6	
	The Citron *Citrus medica.*	The fruit		Messina		40 cwt.	180 cwt.	25 cwt.	40 cwt.	
	Essence of Bergamot *Citrus Bergamia.*			Messina			250 lbs.			
	The Shaddock *Citrus decumana.*	The fruit		Jamaica			4 cwt.		16 cwt.	
					bushels.	bushels.	bushels.	bushels.	bushels.	
	The Orange *Citrus aurantium.*	The fruit		Spain	1,539	5,751	5,439	8,098	11,444	
				Portugal	10,918	21,133	23,269	30,199	26,403	
				Sicily	1,170	553	232	1,231	14,293	
				Jamaica		6	2			
				St. Michael				4,081	3,157	
				Matanzas				2		
				Berbice				3		
				Malta					1,322	
				Morocco					2	
					13,627	27,443	28,942	43,614	56,622	

		The living plant.		Seville			8			
				Palermo				2		
		The peel or rind preserved.		Messina	cwt. 25	cwt. 190	cwt. 80	cwt. 555	cwt. 60	
				Malaga				50		
				Palermo				170		
					25	190	80	775	60	
		The essence		Messina	2 cwt.					
	Tangerines *Citrus aurantium*, var. Tangerine Orange.	The fruit		Lisbon			bushels. 9	bushels.	bushels. 30	
				Oporto					12	
							9		42	
Amyridaceæ.	Gum Olibanum *Boswellia thurifera.* *B. glabra.*			Bombay		3 cwt.				
Cedrelaceæ.	Mahogany *Swietenia Mahagoni.*	The timber	Honduras, Cuba, St. Domingo.	St. Domingo	logs. 4049	logs. 986	logs. 725	logs. 28	logs.	5*d.* to 1*s.* 6*d.* on the average per superficial foot.
				Honduras		812	1015	422	379	
				Cuba		214	680		547	
				Jamaica				44	103	
					4049	2012	2420	494	1029	
	Cedar Wood *Cedrela odorata.*	The timber		Surinam	logs.	logs.	logs. 28	logs.	logs.	4½*d.* per superficial foot.
				Honduras			8			
				Cuba					63	
							36		63	
	Cedar (same as Cedar Wood)			Jamaica				50 deals.		3*d.* per superficial foot.
	Red Wood *Soymida febrifuga.*			Mauritius		pieces. 2024		pieces.		
				Madras				4207		

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Cedrelaceæ.	Satin Wood *Chloroxylon Swietenia?.*	The timber	...	Pernambuco	...	...	8 pieces.			
Meliaceæ.	Crab Oil or Carapa *Carapa Guianensis.*	Expressed oil of seed.	Guiana	...	...	...	...	...	...	Small quantities imported for medical purposes.
					tons.	tons.	tons.	tons.	tons.	
Anacardiaceæ.	Sumach *Rhus typhina. R. Cotinus. R. glabra. R. coriaria.*	Bark and leaves for dyeing and tanning.	...	Sicily	1191	980	1320	1893	1869	
				France	...	100	33	24		
				Spain	...	...	4			
				Trieste	...	...	...	43	127	
				Malta	...	...	...	...	43	
				Italy	...	...	...	...	36	
					1191	1080	1357	1960	2075	
					tons.	tons.	tons.	tons.	tons.	
Zygophyllaceæ.	Lignum Vitæ *Guaiacum officinale.*	The heartwood	West Indies	St. Domingo	80	...	...	10		
				Matanzas	...	...	...	12		
				Honduras	...	...	...	...	4	
				Jamaica	...	1				
					80	1		22	4	
					tons.	tons.	tons.	tons.	tons.	
...ceæ.	Flax *Linum usitatissimum.*	The fibre	...	Russia on Baltic.	518	50	...	960	523	
				Leghorn	69	18	...	...	21	
				Alexandria	19	295	105	8		
				Malta	8					
				Rotterdam	47					
					661	363	105	968	544	
					bushels.		bushels.			
		The seed	...	Picton, N. S.	35	...	21			
				New York	350					
					385		21			

Lina-	Linseed *Linum usitatissimum.*	The seed	…	Bombay	bushels. 16,102	bushels. 9975	bushels.	bushels.	bushels.
				Hamburg	105				
				Naples	21				
				Montreal	…	6			
				Riga	…	…	…	1575	
				Sicily	…	…	…	…	346
					16,228	9981		1575	346
		Oil expressed from seeds.	…	Rotterdam	…	27 tuns.			
		Oil-cake	…	New York	tons. 459	tons. 231	tons. 36	tons. 9	tons.
				Montreal	10	8	82	81	13
				Bordeaux	…	…	10		
					469	239	128	90	13
		Oil-cake	Europe and America.	New York	cwt. 373	cwt. 100	cwt. …	cwt. 500	cwt.
				Hamburg	4				
				Montreal	…	532			
				Trieste	…	…	…	…	185
				Leghorn	…	…	…	…	1840
				Venice	…	…	…	…	1
					377	632		500	2026
Polygo-naceæ.	Buckwheat *Fagopyrum esculentum.*	The seed	…	New York	qrs. 15	qrs. 5	qrs. 10	qrs. 20	
				France	600				
					615	5	10	20	
Piperaceæ.	Pepper *Piper nigrum.*	The dried berry.	Bombay and Moluccas.	Bombay	lbs. 174,900	lbs. 158,620	lbs. 44,000	lbs. 224,510	lbs. 8140
				Singapore	50,300	103,800	23,900	165,500	
				Melbourne	(returned	cargo.)	28,600		
					225,200	262,420	96,500	390,010	8140

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Lauraceæ.	Cassia-Lignea *Cinnamomum Cassia.*	The bark		Hamburg	cwt. 38	cwt.	cwt. 10			
				Singapore		62	32			
					38	62	42			
	Cinnamon *Cinnamomum Zeylanicum.*	The bark		Rotterdam	100 lbs.					
	Camphor *Camphora officinarum.*	Procured from the wood by distillation.		Rotterdam	3 cwt.					
	Greenheart Wood *Nectandra Rodiæi.*	The timber used in ship-building	Demerara	Demerara	tons. 55	tons. 66	tons. 125	tons. 56	tons. 185	4*s.* 6*d.* per cubic foot.
				Berbice					99	
					55	66	125	56	284	
		The bark		Berbice	cwt.	cwt. 110	cwt. 13	cwt.	cwt. 50	
				Demerara		5	23	72	44	
				Surinam					1	
						115	36	72	95	
		The seed		Berbice			4 cwt.		9 cwt.	
				Demerara			7 cwt.			
Ana-cardi-aceæ.	Cashew Nuts *Anacardium occidentale.*	Kernel edible; pericarp acrid		Grenada					5 bushels	
	Peas *Pisum sativum.*	The seed		New York	qrs. 304	qrs.	qrs. 227	qrs. 2269	qrs. 468	
				Montreal	6988	2630	2603	1998	6414	
				Holland	80	117	10			
				Prussia	15	6				
				Hamburg		37	125			
				Denmark		20		110		
				Alexandria			25			

				Morocco	....	....	32		
					7387	2810	3022	4377	6882
Leguminosæ. Suborder Papilionaceæ.	Beans *Faba vulgaris.*	The seed	....	Alexandria Oldenburg Holland Hanover France New York Denmark Hamburg Morocco Belgium Sicily	qrs. 15,206 328 28 1,315 600 96	qrs. 15,734 598 100 645 .... 1,136 496	qrs. 14,069 882 325 630 590 149 400	qrs. 15,871 764 1,011 .... 217 800 18	qrs. 17,506 3,288 5,591 745 915
					17,573	18,709	17,045	18,681	28,045
	Haricot Beans *Phaseolus vulgaris.*	The seed	....	Charente New York	....	....	2 cwt.		 62 cwt.
	Lentils *Ervum lenticula.*	The seed	....	Alexandria	....	150 qrs.	195 qrs.	1041 qrs.	
	Lupins *Lupinus albus.*	The seed	....	Alexandria	....	....	16 qrs.		
	Clover *Trifolium repens.* *T. Pennsylvanicum.*	The seed	....	New York Hamburg France Italy	bushels. 324	bushels. 2298 156 2358	bushels. 60 4026	bushels. 1116 2640	bushels. 2700 1182 1206
					324	4812	4086	3756	5088
	Liquorice (Paste and Juice) *Glycyrrhiza glabra.*	The root	....	Italy Sicily Spain	cwt. 1096 648	cwt. 284 168	cwt. 1704 498 114	cwt. 322 196 50	cwt. 1724 158
					1744	452	2316	568	1882

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Leguminosæ. Suborder Papilionaceæ.	Tonquin Beans .... *Dipterix odorata.*	Used for flavouring snuff.	....	New York	....	....	....	....	12 cwt.	
	Gum Tragacanth............ *Astragalus gummifer.* *A. verus.*	The gum	....	Smyrna	60 cwt.					
	Rosewood .... *Triptolomæa.*	The timber	Brazil principally	Bahia	22 tons.	29 tons.	5 tons.	....	11 tons.	
Leguminosæ. Suborder Mimoseæ.	Gum Arabic............ *Acacia vera.* *A. arabica.*	Exudation from the bark.	....	Bombay	cwt. 60	cwt. 501	cwt. 275	cwt. 303		
				Smyrna	....	108				
				Alexandria	....	102				
					60	711	275	303		
	Gum Senegal .... *Acacia gummifera.* *A. Senegal.*	The gum	....	France...	891 cwt.	....	2376 cwt.			
	Gum Ghatty .... *Acacia* (sp.?).	The gum	....	Bombay	180 cwt.					
	Gum............ (Not specified.)	....	....	New York	cwt.	cwt.	cwt.	cwt.	cwt. 333	
				Trieste	....	....	....	....	204	
				Port Natal	....	33				
				Corisco Bay......	....	....	....	12		
						33	....	12	537	
	Cutch or Catechu .... *Terra Japonica.* *Acacia Catechu.*	Inspissated decoction of wood; used in tanning and dyeing.	....	Moulmein	....	....	20 tons.	28 tons.		
	Algarobilla .... *Prosopis* (sp.?).	The seed	....	Messina	....	....	....	....	1693 bahs.	

Leguminosæ. Suborder Cæsalpinieæ.	Logwood ...... *Hæmatoxylon Campechianum.*	The heartwood...	Campeachy, Honduras, St. Domingo, Jamaica.		tons.	tons.	tons.	tons.	tons.
				New York	1318	1154	711	869	280
				Boston	178	230	......	......	238
				St. Domingo ...	593	315	555	1220	725
				Belgium	19				
				Hamburg	26				
				Jamaica	62	318	310	1357	1460
				Honduras	......	143	201	137	139
				Halifax	......	15			
				Valparaiso	......	......	......	5	
				Cuba	......	......	......	18	
					2196	2175	1777	3606	2842
	Brazil Wood ...... *Cæsalpinia echinata?* *C. brasiliensis.* *C. crista.*	The timber	......	Valparaiso	......	5 tons.			
				Callao	......	......	......	......	5 tons.
	Lima Wood ...... *Cæsalpinia echinata.*	The timber	......	Callao	......	......	......	......	206 tons.
				New York	......	......	30 tons.		
	Acapulco Wood?	......	......	Callao	......	......	......	......	25 tons.
	Locust Wood ...... *Hymenæa Courbaril.*	The timber	West Indies......						tons.
				New York	......	......	......	......	16
				Trinidad	......	......	......	......	3
									19
	Nicaragua Wood ...... *Cæsalpinia echinata.*	The heartwood, used as a dye.	......	Valparaiso	......	......	......	10 tons.	
	Sapan Wood ...... *Cæsalpinia Sapan.*	The wood; used as a dye.	Manilla, Siam ...		tons.	tons.	tons.	tons.	tons.
				Singapore	20	10	11	4	
				New York	95				
				Java	......	44	2		
				Manilla	......	35	19	......	75
				Batavia	......	10	1		
					115	99	33	4	75

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Leguminosæ. Suborder Cæsalpinieæ.					tons.	tons.	tons.	tons.	tons.	
	Barwood .... *Baphia nitida ?*	The heartwood, used as a dye.	Angola and Gaboon in Africa.	Corisco Bay......	....	....	375	250	650	
				River Moondah..	....	....	348	198	250	
							723	448	900	
	Purple-heart Wood............ *Copaifera pubiflora. Copaifera bracteata.*	The timber used in ship-building.	....	Pernambuco ...	....	....	29 pieces.			
	Mora Wood..................... *Mora excelsa.*	The timber used in ship-building.	British Guiana...	Demerara...	....	....	....	32 logs.	84 logs.	4*s.* 6*d.* per cubic foot. Used for ship-building purposes.
	Tonker Wood .... (*Mora ?*)	The timber	Guiana...........	Demerara........	....	90 logs.	....	....	....	1*s.* 6*d.* per cubic foot.
					cwt.	cwt.	cwt.	cwt.	cwt.	
	Locust Beans .... *Ceratonia siliqua.* (Carob Tree).	Legume; used for feeding cattle.	....	Malaga..........	....	292	....	270		
				Xabea	....	38	....	40		
				Messina	....	....	....	....	358	
				Venice	....	....	....	....	112	
						330	....	310	470	
					lbs.	lbs.	lbs.	lbs.	lbs.	
	Tamarinds .... *Tamarindus indica.*	The fruit preserved.	West Indies.....	Grenada	90	160	98	61	120	
				Barbadoes	60	10	132			
				Trinidad	432	280	66	550	390	
				Jamaica	240	440	588	360	230	
				St. Vincent	110	30	....	180		
				St. Kitts	200	250	14	210	60	
				Berbice	30	....	38	84	50	
				Demerara	20	60	28	150	20	
				Porto Rico	170					
				Antigua	....	120	....	560		
				Tobago...........	....	40	98	20		
				St. Domingo ...	....	10				
				Montserrat	....	....	28			

				Surinam	....	....	21		
				Matanzas	....	....	....	20	
				Newfoundland	....	....	....	235	
				Mauritius	....	....	....	20	
					1852	1430	1106	2670	840
	Senna *Cassia lanceolata. C. elongata.*	The leaves	....	Bombay	30 lbs.	88 lbs.			
	Cassia Fistula *Cathartocarpus Fistula.*	Pulp of the legume; used as a laxative medicine.	....	St. Domingo	8 cwt.	5 cwt.	3 cwt.		
Rosaceæ.	The Rose *Rosa damascena. R. moschata, &c.*	Otto or Attar of Roses, the essential oil.	....	Malta	2 lbs.				
		Rose water	....	Smyrna	3 gallons.				
Rosaceæ. Suborder Pomeæ.	The Apple *Pyrus malus.*	The fruit	....	France	bush. 2,750	bush. 18,401	bush. 3,409	bush. 9,946	bush. 3,657
				Denmark	800				
				Jersey	700	15,748	1,200	13,771	27,740
				Hanover	1,800	1,260	750	1,400	4,402
				New York	4,551	1,296	220	6,414	1,311
				Montreal	600	504	398	603	942
				Quebec	5	209	132	....	137
				Picton, N. S.	225				
				St. John's, N.B.	....	13			
				Halifax	....	301			
				Newfoundland	....	....	....	12	
				Portugal	....	....	....	....	18
					11,431	37,732	6,109	32,146	38,207
		Living plants	....	New York	....	....	....	....	6
	Cider. The Apple *Pyrus malus.*	The juice fermented.	....	New York	gallons. 1500	gallons. 300	gallons.	gallons. 83	gallons. 350
				Montreal	50	....	....	50	
				Jersey	....	....	....	....	100
					1550	300	....	133	450

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Rosaceæ. Suborder Pomeæ.	The Quince *Cydonia vulgaris.*	The fruit	...	New York	...	...	...	2 cwt.	1 cwt.	
					bush.	bush.	bush.	bush.	bush.	
	The Pear *Pyrus communis.*	The fruit	...	Jersey	...	52	...	22	20	
				France	...	866				
				Quebec	...	14				
				Portugal	...	...	...	4		
					...	932	...	26	20	
Rosaceæ. Suborder Amygdaleæ.					cwt.	cwt.	cwt.	cwt.	cwt.	
	The Almond *Amygdalus communis*, and var. *amara.*	The kernel	...	Spain	334	479	1651	770	593	
				France	63	259	286	2	35	
				Sicily	190	54	49	...	45	
				Alexandria	...	90	...			
				Morocco	...	...	...	8	130	
				Portugal	...	...	...	...	31	
					587	882	1986	780	834	
	The Apricot *Prunus Armeniaca.*	The fruit	...	Oporto	...	18 bush.	4 bush.	2 bush.		
	The Peach *Amygdalus Persica.*	The fruit	...	New York	...	...	...	2 cwt.	5 cwt.	Six peach plants were imported from New York in 1857.
					cwt.	cwt.	cwt.	cwt.	cwt.	
	The Plum *Prunus domestica*, var. *Catharina.*	The dried fruit	...	France	800	815	706	597	1207	
				Portugal	1	48	42	47	6	
					801	863	748	644	1213	
					cwt.	cwt.	cwt.	cwt.	cwt.	
	The Prune *Prunus domestica*, var. *Juliana.*	The dried fruit	...	France	36	79	84	116	11	
				Hamburg	3	1				
				Sicily	16	...		...	12	
				Spain	...	...	68			
					55	80	152	116	23	

Rhamnaceæ.	Persian Yellow Berries (Turkey Berries). *Rhamnus infectorius. R. saxatilis. R. amygdalinus.*	Berries yield a yellow dye.	…	Smyrna	381 cwt.	285 cwt.	…	…	600 cwt.	
				New York	32 cwt.					
Sapotaceæ.	Gutta-Percha. *Isonandra Gutta.* (Taban Tree.)	The milky juice hardened.	Indian Archipelago.	Singapore	445 cwt.					
	Bullet-tree Wood. *Achras Sapota.*	The timber	…	Berbice	…	12 logs.	…	…	…	4*s.* per cubic foot.
Ebenaceæ.	Green Ebony & Black Ebony. *Diospyros* (sp.?).	The heartwood	…	Jamaica	…	14 tons.	5 tons.	15 tons.	6 tons.	
				Corisco Bay	…	…	…	250 pieces		
Gentianaceæ.	Gentian. *Gentiana lutea?.*	The root	…	Marseilles	…	…	…	10 cwt.		
Oleaceæ.					bushels.	bushels.	bushels.	bushels.	bushels.	
	The Olive. *Olea europæa.*	The fruit pickled	South of Europe	Cadiz	8	9	42	…	40	
				Seville	240	56	1371	90	48	
				Lisbon	9	6	…	4	4	
					257	71	1413	94	92	
					tuns.	tuns.	tuns.	tuns.	tuns.	
	Olive Oil. *Olea europæa.*	Oil expressed from drupaceous fruit.	…	Malta	303	158	437	…	43	
				France	299	76	…	1	21	
				Sicily	10	162	92	170	170	
				Italy	146	85	538	392	739	
				Gallipoli	148	97				
				Toronto	…	269	…	152		
				Spain	…	29	350	79	162	
				Portugal	…	…	21	224	71	
				Smyrna	…	…	90			
				Morocco	…	…	73	200	341	
				Corfu	…	…	…	168		
				Trieste	…	…	…	20		
					906	876	1601	1406	1547	

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Oleaceæ.	Manna (Ash) *Ornus rotundifolia. O. europæa.*	Exudation from the branches.		Archangel	200 lbs.			210 lbs.	360 lbs.	
				Palermo		350 lbs.				
	The Ash *Fraxinus excelsior.*	The timber	N. America	Quebec	pieces. 632	pieces. 357	pieces. 313	pieces. 185	pieces. 743	1*s.* 6*d.* per cubic foot.
				Quebec	staves. 5638	staves. 4000	staves. 3500	staves. 5000	staves. 2204	
Solanaceæ.	Seed Potatoes *Solanum tuberosum.*	The tuber			cwt.	cwt.	cwt.	cwt.	cwt.	
				Quebec			20			
				New York					8	
				Lisbon					30	
							20		38	
	Tobacco *Nicotiana Tabacum.*	The leaves	America and tropical countries.		cwt.	cwt.	cwt.	cwt.	cwt.	
				New York	9027	5454	3336	4122	2304	
				New Orleans	38					
				Alexandria	207		261			
				Richmond			2376			
				Montreal				2268		
					9270	5454	5973	6390	2304	
	Tomatoes *Lycopersicum esculentum.*	The fruit pickled		Bordeaux					5 cwt.	
		Sauce		Bordeaux					7 cwt.	
	Cayenne Pepper *Capsicum annuum.*			Demerara		140 lbs.				
Labiatæ.	Lavender *Lavandula vera.*	The essential oil of the flowers.		Lisbon		212 lbs.				
	Peppermint *Mentha piperita.*	The essential oil.		New York	8 galls.	55 galls.	9 galls.	57 galls.	135 galls.	

Verbenaceæ.	Teak *Tectona grandis.*	The timber used in ship-building.		Moulmein Sierra Leone	logs. 1439	logs. 2998 576	logs. 362	logs. 2884	logs. 2417	5s. 6d. per cubic foot.
				Moulmein	1439 200 plks.	3574 859 plks.	362 120 plks.	2884 1929 plks.	2417 1985 plks.	
Pedaliaceæ.	Gingilee or Gingelly Oil *Sesamum orientale.*	Oil expressed from the seeds, called Teel seeds		Bombay					10 tuns.	£45 per tun. A fixed oil, employed in adulterating oil of almonds.
	Sesamum *Sesamum orientale.*	Seeds yield oil		Mogadore			30 bushs.			
Compositæ. Suborder Cichoraceæ.	Chicory *Cichorium Intybus.*	The root		Hanover Hamburg Rotterdam	cwt. 20 503 40	cwt. 48	cwt. 82			
					563	48	82			
	Lettuce *Lactuca sativa.*	The seed		Oporto			4 bushels.			
Combretaceæ.	Myrabolams or Myrobalans *Terminalia belerica.* *T. Chebula.*	Seeds used in tanning and dyeing.		Bombay	650 cwt.		140 cwt.	135 cwt.		
Myrtaceæ.	Pimento *Eugenia Pimenta.* *E. acris.*	The fruit	Jamaica	Jamaica	2 cwt.	1082 cwt.	118 cwt.	700 cwt.	862 cwt.	
	Cloves *Caryophyllus aromaticus.*	Unexpanded flower-bud.	Moluccas, West Indies.	Holland Singapore Bombay	88 cwt.	 72 cwt.		 106 cwt.	 198 cwt.	
		The oil		Hamburg	3 galls.					
	Kayie Putch Oil, Cajeput Oil *Melaleuca minor.*	Obtained from the leaves.		Sourabaya		350 galls.				The pungent oil dissolves Caoutchouc. Employed medicinally.
	The Pomegranate *Punica Granatum.*	The fruit		Spain Portugal	301	780	640	1080 60	660 50	
					301	780	640	1140	710	

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.	Observations.
Myrtaceæ.	Guava Jelly .... *Psidium pyriferum.* *P. pomiferum.*	The fruit	....	Matanzas	....	....	....	220 lbs.		
					cwt.	cwt.	cwt.	cwt.	cwt.	
Vacciniaceæ.	Cranberries .... *Oxycoccos macrocarpa.*	The fruit	....	Quebec........	3					
				Newfoundland...	....	15	....	5	3	
				Miramichi	....	....	4			
				New York	....	....	....	3	51	
					3	15	4	8	54	
					cwt.	cwt.	cwt.	cwt.	cwt.	
Cinchonaceæ.	Coffee .... *Coffea Arabica.*	The seed	....	Holland	75	196				
				Belgium	3					
				Surinam	48	20	35	52		
				Brazil	237	....	....	3		
				St. Domingo ...	1095	30	780	525	3100	
				Berbice	2	....	....	2	4	
				Demerara........	8	36	6	10	6	
				Porto Rico	4	....	4			
				Grenada	2	....	2			
				Jamaica	83	6	103	38	73	
				Trinidad	8	4	6	9		
				Bombay	....	94	79	474		
				Sourabaya	....	9				
				Singapore	....	....	496	6		
				Calcutta	....	....	....	8		
				Iquique	....	....	....	1		
					1565	395	1511	1128	3183	
	Chayroot .... *Oldenlandria umbellata.*	Root used as substitute for madder.	....	Calcutta	....	....	....	48 cwt.		
	Gambier (Catechu)........ *Uncaria Gambier.* A variety of Catechu.	Prepared by the Malays from the leaves, and used in tanning.	....	Singapore	....	....	1094 cwt.			

Galiaceæ.	Madder Roots *Rubia tinctorum.* *R. cordifolia.*	The root used in dyeing.	France, Holland, and the Levant, Bombay. (*Munjista.*)		tons.	tons.	tons.	tons.	tons.	The roots of *R. cordifolia* yield the dye called Munjeet in India.
				France	1107	1101	571	187	1020	
				Smyrna	700	406	471	....	626	
				Bombay	54	308	302	136	66	
				Malta	8	1	....	....	4	
				Naples	91	382	315	815	454	
				Alexandria	....	101	....	....	3	
				Sicily	....	....	....	18		
					1960	2299	1659	1156	2173	
	Madder *Rubia tinctorum.* *R. peregrina.*	The root, ground	Holland, Smyrna		tons.	tons.	tons.	tons.	tons.	
				Holland	196	54				
				France	934	1276	540	1017	1081	
				Alexandria	....	48				
					1130	1378	540	1017	1081	
		Garancine, a powder prepared from Madder root.	....		tons.	tons.	tons.	tons.	tons.	
				France	72	78	86	21	292	
				Holland	13	12				
					85	90	86	21	292	
Umbelliferæ.	Aniseed *Pimpinella Anisum.*	Oil expressed from the seed.	....	Marseilles	....	40 bshls.				
	Caraway *Carum Carui.*	Achenes used chiefly by confectioners.	....		bushels.	bushels.				
				Hamburg	404	332				
				Rotterdam	1588	796				
					1992	1128				
	Cummin-seed *Cuminum Cyminum.*	Yields an oil	....	Mogadore	....	....	140 bshls.	486 bshls.		
Caprifoliaceæ.	Elder Berries *Sambucus nigra.*	The fruit	....	Portugal	6 cwt.					

Miscellaneous Vegetable Substances not classified, and uncertain.

Substances.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports. 1857.	Observations.
Oak Staves, Red			Quebec	80,000	75,000	83,000	90,000	140,000	£16 per 1000.
White			Quebec	70,000	69,000	71,000	73,000	122,500	
Pipe Staves			Quebec	85,000	89,000	80,000	79,000	100,000	£45 per 1000.
Hogshead, Puncheon, and Claret Staves.			United States	120,000	100,000	114,000	125,000	130,000	£20 per 1000.
				bundles.	bundles.	bundles.	bundles.	bundles.	
Wood Hoops			Rotterdam	21,473	6,744	6,370			Large quantities are imported through Grangemouth. They are principally made of Ash, and are used for coopering purposes.
			Newfoundland	486	81	2,452	1,466	171	
			Hamburg	5,460					
			New York	74					
				27,493	6,825	8,822	1,466	171	
Angica Wood, Cangica Wood Species of *Triptolomæa*?			Pernambuco			6 tons.			
Granadillo Wood. Variety of Cocus Wood. Uncertain.			Cuba			27 tons.			
Roble?			Marseilles	2 logs.					
				tons.	tons.	tons.	tons.	tons.	
Ashes	Residuum of burnt timber, yielding carbonate of potash.		New York	21		26	70	252	
			Montreal	2368	1909	1791	2371	2424	
			Quebec	59					
			Portland					62	
				2448	1909	1817	2441	2738	
Cocoa Shell (Cocoa Palm?.)			Alicante				50 cwt.		
			Denia					20 cwt.	
Vegetable Hair			Bordeaux					2 cwt.	
Capsules			Bordeaux		2 cwt.			3 cwt.	

Moss			New Orleans			15 cwt.	6 cwt.	4 cwt.
Silk-grass. (Pine-Apple Fibre?).			Tobago				a quantity	
Naphtha	Obtained from the oils of Coal, &c.		New York	tuns. 23	tuns. 13	tuns. 47	tuns. 26	tuns. 31
			Marseilles		4			
				23	17	47	26	31
Pyroligneous Acid Wood-Vinegar.	Obtained by distilling oak, birch, &c.		New York	435 cwt.	675 cwt.			
Calavanca	A bean used in soup as substitute for potato.		New York					5 cwt.
Varnish	Made by dissolving resins in alcohol, &c.		Savannah		18 cwt.		25 cwt.	
Argol, Tartar, and Cream of Tartar, Bitartrate of Potash.		Wine-growing countries.	France	cwt. 195	cwt. 429	cwt. 260	cwt. 975	cwt. 299
			Spain	13				
			Italy	1586	1144	52	247	117
			Sicily	247	104		637	767
			Oporto				169	
			Trieste					182
				2041	1677	312	2028	1365
Gray Tartar (See above.)			Ancona	325 cwt.				
			Trieste					26 cwt.
Yellow Tartar (See above.)			Ancona	221 cwt.				
			Trieste					65 cwt.
Farina Uncertain, but probably from Flour and Potatoes.			New York	cwt. 140	cwt. 10	cwt.	cwt. 8	cwt. 12
			Rotterdam		150			
			Montreal				1	
			Barbadoes				1	
			Trinidad					2
				140	160		10	14

MINERAL SUBSTANCES.

Substances.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.
		cwt.	cwt.	cwt.	cwt.	cwt.
Alabaster	Leghorn	36	116	63	18	52
	Marseilles	...	...	...	...	10
		36	116	63	18	62
Roman Cement	Ancona	...	46 tons.			
		tons.	tons.	tons.	tons.	tons.
Marble	Leghorn	308	516	248	264	3968
	Salonica	28				
	Sicily	...	8			
	Antwerp	...	28			
	Bordeaux	...	16	...	8	17
	Hamburg	...	...	2		
	New York	...	...	1		
	Athens	...	...	...	18	
		336	568	251	290	3985
Stucco	Rouen	...	...	...	...	20 tons.
Plaster of Paris	Havre	85 tons.				
Limestone	France	60 tons.	45 tons.	...	160 tons.	60 tons.
Chalk	Leghorn	2 tons.				
	Rouen	...	...	...	50 tons.	150 tons.
		cwt.	cwt.	cwt.	cwt.	cwt.
Pumice Stone	Messina	...	556	...	855	93
	Palermo	...	408	72	57	
	Malta	...	66			
	Leghorn	...	...	...	153	60
		...	1030	72	1065	153
Porcelain	Rouen	...	...	...	2 cwt.	
Emery Stones	Smyrna	351 tons.	...	90 tons.		
Barytes	Rotterdam	30 tons.				
Magnesia	New York	...	37 cwt.			
Borax	...	...	...	...	140 cwt.	
		tons.	tons.	tons.	tons.	tons.
Nitrate of Soda	Iquique	175	...	243	1655	
	Valparaiso	647	...	...	...	400
		822	...	243	1055	400
Natron (Carbonate of Soda)	Alexandria	...	20 tons.			
Alkali	Rouen	...	...	980 galls.		

Substances.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.
		tons.	tons.	tons.	tons.	tons.
Salt (Common)	Portugal	213	160	....	295	3
	France	....	80			
	Alexandria	....	....	95		
		213	240	95	295	3
Saltpetre	Calcutta	....	....	....	156 tons.	30 tons.
		tons.	tons.	tons.	tons.	tons.
Brimstone	Sicily	3401	9938	4240	8977	3448
	France	568	835	....	165	206
	Italy	370	26	....	....	25
	Malta	191	110	43	....	
	Alexandria	....	60	....	....	280
	Portugal	....	....	....	230	
	New York	....	....	....	....	155
		4530	10,969	4283	9372	4114
		tons.	tons.	tons.	tons.	tons.
Manganese	Rotterdam	27	....	....	8	
	St. John's, N. B.	....	....	....	110	
	Marseilles	....	....	....	....	4
	Leghorn	....	....	....	....	22
		27	....	....	118	26
Manganese Ore	Rotterdam	945 tons.	333 tons.	331 tons.	230 tons.	
	St. John's, N. B.	....	....	....	....	20 tons.
		tons.	tons.	tons.	tons.	tons.
Lead	Spain	293	49	78	149	71
	France	160	....	....	....	12
	Montserrat	....	....	3		
		453	49	81	149	83
		tons.	tons.	tons.		
Litharge	Hamburg	17	7			
	Rotterdam	6	15	4		
		23	22	4		
Iron	Cronstadt	....	....	....	2209bars.	
Iron Ore	New York	....	....	....	20 cwt.	
Sienna Earth .... (Hydrous Sesquioxide of Iron.)	Leghorn	144 cwt.	87 cwt.	....	42 cwt.	129 cwt.
Pig Iron	St. John's, N. B.	....	....	....	14 tons.	
	St. Petersburg	....	....	....	10 tons.	
Ochre	Nantes	300 tons.				
	Rouen	....	....	....	10 tons.	
		cwt.				
Plumbago	Rotterdam	1				
	St. John's, N. B.	6	small	quantities	occasiona	lly.
		7				

Substances.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.
		tons.	tons.			
Chromate of Iron	Smyrna	50	155			
	New York	...	50			
		50	200			
Copperas	Rouen	...	...	...	...	150 cwt.
Pyrites (Bisulphuret of Iron.)	Drontheim	...	...	...	...	60 tons.
		cwt.	cwt.	cwt.	cwt.	cwt.
Spelter or Zinc	Hamburg	778	678	148	549	
	Antwerp	...	2282	790	893	916
	Rotterdam	...	155			
	Palermo	...	...	...	...	10
		778	3115	938	1442	926
		cwt.	cwt.	cwt.	cwt.	cwt.
Copper	St. Kitts	20				
	Quebec	...	190			
	Grenada	...	...	21		
	Trinidad	...	...	1		
	Valparaiso	...	...	...	20	
	Jamaica	...	...	...	1	
	St. Vincent	...	...	...	1	
	Malta	...	...	...	...	1
	Callao	...	...	...	...	5
		20	190	22	22	6
Verdigris	New York	...	...	7 cwt.		
		packages.	packages.			
Gold	Melbourne	2				
	New York	...	1			
	Jamaica	...	1			
		2	2			
Pewter	Demerara	...	...	...	...	10 cwt.
Asphalte	Cardenas	...	560 cwt.			
Lapis Lazuli Ultramarine.	Callao	...	...	...	...	4 cwt.
Terra Umbra	Malta	20 tons.				
Drip-stone	Sourabaya	...	...	3 cwt.		
				tons.	tons.	
Glass Sand	Rouen	...	...	473	217	
	Lisbon	...	...	...	60	
				473	277	
Earth, or Painters' Colours	Montreal	60 cwt.				
Chrome Ore	St. Petersburg	30 tons.				
	New York	...	964 tons.	300 tons.		
	Cronstadt	...	...	...	40 tons.	

Substances.	Whence Imported.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Imports, 1856.	Imports, 1857.
Chrome Yellow	Rotterdam	10 cwt.				
Burr Stones	France	1045	2205	4057	624	4892
Sal-ammoniac	Rotterdam	3 cwt.				
Acetate of Lime	New York	1825 cwt.	1611 cwt.	1924 cwt.	1976 cwt.	2072 cwt.
Vitriol	Hamburg	....	250 galls.			
		gallons.	gallons.	gallons.	gallons.	
Mineral Water	Hamburg	600				
	Rotterdam	550				
	Marseilles	....	....	....	2000	
		1150	....	....	2000	
Seltzer Water	Amsterdam	....	....	....	645 galls.	
Chromate ?	Oporto	....	....	....	238 cwt.	

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.

The Committee, so appointed, consisted of the following gentlemen:—

Admiral Moorsom. Charles Atherton. Henry Wright.
J. Scott Russell. William Fairbairn. Andrew Henderson.
J. E. McConnell. James Perry.

The Committee, on commencing their proceedings, received letters from Admiral Moorsom, Mr. John Scott Russell, and Mr. J. E. McConnell, whereby the Committee were deprived of the co-operation of those gentlemen as members of this Committee; the remaining members, however, agreed to prosecute the duties assigned to them, and William Fairbairn, Esq., F.R.S., by the unanimous desire of the Committee, undertook to conduct the proceedings as Chairman, with the assistance of Henry Wright, Esq., as Honorary Secretary. The Committee now beg to explain the course of proceeding by which they hoped to promote, if not mature, the objects assigned to them by the Association.

In the first place, the Committee issued a circular, inviting statistical information as to the actual sea performances of ships (Appendix No. 1), with a view to compiling a comprehensive statement as to the sea performances of vessels generally, whence the Committee might be enabled to select a considerable number of vessels, of which the performances at sea may have been remarkable; and their attention being thus directed to a limited selection, embracing a considerable number of vessels of practically established excellence for sea service, the Committee hoped, after making due inquiry, to be enabled to present, as respects those vessels, a statistical exposition, in tabular form, of their various elements of construction and type of build, and thus, by a system of collation and induction, to discover practically those types and elements of construction which have been found by experience most conducive to good performances at sea. In the case of steam-ships, it was purposed that the statistics of the original trials to which steamers are generally put when new, should also be collected, classified, and collated with reference to the subsequent performances of the same vessels at sea, whence it might be determined to what extent and in what respects the usual smooth-water trials of steam-ships may be indicative of the probable properties to be expected of the same ships at sea, as respects their dynamic capabilities.

The Committee are happy to say that this attempt at practically inquiring into the peculiarities of construction to which the good or bad qualities of steam-ships may be attributable, has not been wholly fruitless; for, although shipowners, shipbuilders, and marine engine manufacturers have been generally reluctant to communicate particulars whereby the dynamic merits of ships may be numerically classed and compared, the results of which classification and comparison might, if promulgated, affect the commercial value of their property and the relative professional reputation of constructors, still, in reply to the before-mentioned circular, information has been communicated as to the performance of vessels, particularly steam-vessels, by which it appears that a great difference exists between steam-ships as respects their economic capabilities for the performance of mercantile steam transport service, leading to the conclusion that the general aggregate of steam service is performed by vessels of inferior adaptation for economic duty, and consequently at a rate of prime-cost expenditure; and, therefore, ultimate charge on the public, greatly in excess of that which would be involved if all steamers were of the superior class of excellence that has been already in certain cases actually attained. For example, this Committee are assured, on authority which they believe to be unquestionable, that a certain vessel, the *Bremen*, of 3440 tons displacement at the time of trial, propelled by engines working up to 1624 indicated horse-power, attained the speed of 13·15 nautical miles per hour. Now, if we estimate the dynamic duty thus performed by the formula $\frac{V^3 D^{\frac{2}{3}}}{\text{Ind.h.p.}}=C$, we shall have the coefficient, $C=\frac{(13{\cdot}15)^3\times(3440)^{\frac{2}{3}}}{1624}=\frac{2274\times227{\cdot}88}{1624}=319$; and this coefficient of dynamic duty, resulting from the mutual relation of displacement, speed, and power, appears, from the statements which have been communicated to this Committee, nearly 50 per cent. higher than that realized by the average performance of the steam-ships of the present day. The following are the coefficients of dynamic duty deduced by the foregoing rule from the performances of mercantile steamers of high repute, of which the trial data have been communicated to this Committee, viz. 325, 294, 291, 288, 259, 248, 231, 230, and 204, and many others below 200.

This Committee therefore regard the *Bremen* as being a felicitous exemplification of naval architecture as respects type of form adapted for easy propulsion; and as we conceive that the promulgation of some of the constructive elements of this vessel may be of public importance, we are happy in being authorized and enabled, by Messrs. Caird and Co., of Greenock, the constructors of the ship and of the engines, to communicate to the British

Association the following statistical data as to the elements of construction of the *Bremen*:—

Length between perpendiculars of stem and rudder post..		318 feet
Breadth of beam		40 „
Depth of hold...		26 „
Mean draught of water at the time of trial		18 ft. 6 in.
Displacement (D) at trial draught		3440 tons
Area of maximum immersed section (A) at the trial draught		606 sq. ft.
Distance of maximum section (A) measuring from the stem		159 feet
Constructors' load draught	forw....	18 „
	aft. ...	19 „
Displacement at constructors' load draught		3440 tons
Rate of ships' displacement at constructors' load draught		25 „ per in.

Data for laying off Peake's curve of sections:—

Area of immersed vertical section at the distance of $\frac{1}{8}$ length, measuring from stem				256·5 sq. ft.
Do.	$\frac{1}{4}$	Do.	Do.......	486 „
Do.	$\frac{1}{2}$	Do.	Do.......	606 „
Do.	$\frac{3}{4}$	Do.	Do.......	489 „
Do.	$\frac{7}{8}$	Do.	Do.......	253·5 „

Data for laying off curve of displacement:—

Displacement at draught of 4′ 7½″, being ¼ load draught.	300 tons
Displacement at draught of 9′ 3″, being ½ load draught..	1165 „
Displacement at draught of 13′ 10½″, being ¾ load draught	2240 „
Displacement at draught of 18′ 6″, or load draught	3440 „

The foregoing data afford all the particulars required for the construction of Peake's curve of vertical sections, whence may be deduced the position of the vertical line passing through the centre of gravity of displacement, and also the positions of the centre of gravity of the fore and aft bodies respectively.

It will be observed, from the foregoing data of the constructive elements of the *Bremen*, that the maximum immersed section is at the middle of the length, and that the vertical sections are in such ratio to each other, with reference to their respective positions, that the curve of vertical sections will be a close approximation to a parabola.

The ratios deducible from the foregoing particulars of constructive data, combining Peake's curve of immersed vertical sections with the curve of displacement, will give a close approximation to the type of form of the immersed hull.

The engines of the *Bremen* consist of two direct-acting inverted cylinders, 90 inches diameter, and 3 feet 6 inches stroke, fitted with expansion valves capable of working expansively to a high degree. All parts of the engines are felted and lagged with wood wherever practicable, the lower 16 feet of the funnel being surrounded by a casing forming a superheating chamber, the steam entering at the lower end, and passing off at the top into the steam pipes leading to the cylinders.

On the important question as to the extent to which the ordinary smooth-water trial of a steamer affords a criterion of the general average performance that may be expected of the vessel at sea, this Committee have not been able to obtain such an extent of returns of the comparative smooth-water trials and sea performances of the same ships as enable them fully to respond to this part of the inquiry, and they refrain from expressing any speculative opinion, because they have adopted the principle which they desire to recommend to the notice of the British Association, that shipping improvement is to be discovered by statistical record and analysis of the constructive elements of ships that have practically shown themselves to possess good sea-properties, rather than by assuming the mere theories of opinionative speculation, from whatever source such opinions may emanate,—in short, that experience of actual performances at sea, statistically recorded and utilized by being made the basis of comparison, is the most reliable base on which to construct an inductive system of progressive improvement in naval architecture and marine-engine construction. This Committee, however, have much satisfaction in being enabled to commence this inquiry by recording the sea performance of the before-mentioned vessel *Bremen*, on a passage from Bremen haven to New York and back, during the months of June and July last, during the whole of which passages indicator cards were frequently taken, and the indicated working power of the engines ascertained. On the out passage the mean displacement was 2878 tons, the mean indicated horse-power was 1078, and the mean speed 10·28 knots per hour, giving a coefficient by the formula referred to=204; but on the return passage the mean displacement was 2990, the mean indicated horse power 1010, and the mean speed at the rate of 11·92 knots per hour, giving a coefficient=348. Hence the mean coefficient of the out and home passage=276, being about 13 per cent. below the coefficient (319) obtained on the smooth-water test-trial of the ship. The state of the weather and the sea was also recorded daily; it appears to have been adverse on the out passage, but favourable on the home passage. The Committee are, therefore, of opinion that, by following up this course of statistical record of the smooth-water trial and subsequent sea performances of ships respectively, a tabular statement might be compiled, showing the probable ratios of the coefficients of smooth water and sea performance, corresponding to the various rates of speed for which steamers may be respectively powered, whence the smooth water test-trials of ships may be made available as approximately indicative of their sea-service capabilities as respects their dynamic properties.

Such are the statistical data of the constructive elements and dynamic capabilities of the *Bremen*, and if all steam-vessels engaged in the mercantile transport service of Britain were equally effective as respects the mutual relations of displacement, speed, and power, that is, capable of producing a coefficient of dynamic capability=319, by the formula referred to, it is probable that the prime-cost expenses of steam-ship transport per ton weight of cargo conveyed on long passages would, on the aggregate of the foreign trade of Britain, be reduced not less than 25 per cent. as compared with the prime-cost expenses incurred by steam-vessels of the average dynamic capability in present use.

The effect of improved type of build on the economy of steam transport per ton weight of goods conveyed, is such as shows the inquiry to be of vital importance in connexion with the management of steam-shipping affairs.

The public importance of improved type of build in a national point of view (for it is the public and not the shipowners who ultimately bear the brunt of expensive transport service) may be judged of from the statistical fact published by the Board of Trade, that no less than 899 steam-vessels (of which 511 are sea-going ships) were employed on the commercial transport service of Britain in 1857. The ratio in which the transport service of the country is performed by the aid of steam appears to be constantly on the increase; and as it is to be expected that mercantile competition will always cause the cost of freight on the general aggregate of the trade of the country to be proportionally ruled by the prime-cost expenses that may be actually incurred in doing the work, it appears manifest that the public economy dependent on the general realization of shipping improvement is a consideration that involves public interest to the extent of millions sterling per annum.

To demonstrate the vast importance of this subject, Appendix No. 2 has been compiled from the returns of the Board of Trade, to show the amount of trade between the United Kingdom and foreign countries during the year 1855. This compilation shows that the tons weight of cargo actually carried in the foreign trade of the United Kingdom in the year 1855 amounted to—

Imports	6,254,259 tons.
Exports	8,370,363 tons.
Total	14,624,622 tons.

Nearly 15 millions of tons weight of sea-borne cargo, conveyed at probably 25 per cent. extra cost beyond what would be incurred if ships of the high order of dynamic merit exemplified by the *Bremen* were only and exclusively employed.

By aid of Appendix No. 2, showing the amount of trade between Great Britain and all foreign countries respectively, parties conversant with shipping affairs will be enabled to estimate approximately the gross amount annually involved in the goods-transport service of Britain. Thus public interests require that the statistical records of shipping should embrace such data as will be availably conducive to shipping improvement, by affording the means of approximately estimating the dynamic capabilities of ships, whereby every ship constructor and ship owner, and the directors of steam-shipping companies, may be enabled to test the dynamic merits and condition of their ships respectively,—a system, which would gradually lead to the adoption of such types only as develope a high order of dynamic duty, and would obviate some of the most serious hazards to which private and public interests are now exposed from vessels being employed on commercial and postal services for which they are not fit.

Only let it be publicly known, as exemplified by the *Bremen*, that steam-ships and their machinery may be so constructed, that on being subjected to a test-trial, the cube of the speed in knots, multiplied by the square of the cube root of the displacement, and divided by the indicated horse power, ought, in the present day, irrespective of future improvement, to produce a quotient or coefficient of dynamic duty equal to the number 319, and that the coefficient deduced from the rule thus enunciated constitutes (*cæteris paribus*) a criterion of the cost price at which steam-ships perform their work; and we shall then soon find that this test of dynamic merit, or the numeral coefficient deduced therefrom, will enter into the calculation of the pecuniary value of steamers to such extent that ships of a low order of dynamic capability will not be built, because they will not sell.

The test of dynamic merit, as above set forth, based on the mutual relations of displacement, speed, and power, presumes on the net power effectively applied in propelling the ship being always in a constant and known ratio to the gross indicated power.

The inquiry, therefore, so far, is of such a nature as demands professional knowledge and skill in order to determine and discriminate between the merit that may be due respectively to the type of form of the hull, and to the construction of the engines, propeller, and boilers; for a good type of hull, propelled by an inferior construction of machinery and boilers, or an inferior type of hull propelled by a good construction of machinery and boilers, may, by the above formula, produce equal results. This Committee, however, consider it of vital importance to the promotion of the objects of this inquiry, viz., "the maturing of a system of statistical record conducive to the improvement of naval architecture," that the owners and charterers of ships, and the directors of shipping companies or agents by whom shipping affairs are conducted, should themselves have the means of ascertaining the relative dynamic merits and working condition of their ships without any reference whatever to the professional assistance of builders or engineers, but be enabled to judge for themselves whether the performance be good or bad by reference to the data afforded by their counting-house records; and this desirable object may be at once effected by the displacement of the ship being known, and by substituting in the foregoing formula the consumption of fuel in a given time (say the weight in cwts. (W) consumed per hour), in lieu of the expression for power, and regarding the hull, machinery, and boilers collectively as an integral equipment of which the coefficient derived from the formula $\frac{V^3 \times D^{\frac{2}{3}}}{W}$ indicates the dynamic condition with reference to the dynamic condition of other vessels tested by the same rule, viz.:—Multiply the cube of the speed by the square of the cube root of the mean displacement, and divide the product by the consumption of fuel per hour expressed in cwts. The quotient indicates the relative dynamic condition of the vessel. For example: a steam-ship (A) performed out and home voyages amounting to 7200 nautical miles in 652 hours, being at the average speed of 11·04 knots per hour, the consumption of coal was 1519 tons, or 30,380 cwts., being at the rate of 47 cwts. per hour, and the mean displacement was 2934 tons. Hence the coefficient of dynamic duty indicative of the merits of the performance on this occasion is $\frac{(11\cdot04)^3 \times (2934)^{\frac{2}{3}}}{47} = \frac{1345\cdot6 \times 205}{47} = 5870$. Again, another vessel (B), with a mean displacement of 840 tons, attains on long-continued service, the average speed of 12·78 knots per hour, with the average consumption of 50·3 cwts. coal per hour, giving a coefficient of dynamic duty $\frac{(12\cdot78)^3 \times (840)^{\frac{2}{3}}}{50\cdot3} = \frac{2087\cdot3 \times 89}{50\cdot3} = 3693$. Thus, in one case (A), the coefficient of dynamic duty, based on the consumption of fuel, is 5870, whilst in the other case (B), it is only 3693; that is, one cwt. of coal in A performs as much dynamically effective work as is performed by $1\frac{6}{10}$ cwt. in the case of B, a discrepancy which may well induce professional inquiry being instituted by the shipowner, whether the inferior performance of B is occasioned by inferior type of form, or foulness of bottom, or inferior principle of mechanical appliances, or inferior management, or bad coal; for these causes, combined, or indeed either one of them alone, may be sufficient to account for the result.

Now, what are the all-important elements of construction thus proposed to be embraced in public records, and thereby made known to the purchasers and charterers of ships with a view to enable such parties to test the economic working capabilities of ships, so conducive to the reformation above referred to? Why, by the rule above enunciated, the displacement corresponding to the constructor's load draught at which the ship may be tried, and to which approximately, as a general rule, the ship may be loaded, becomes the only item of statistical data that requires to be officially recorded, for the test trial and sea performances of ships, as above shown, will give the capabilities for speed; and the consumption of fuel per hour corresponding thereto will be known from the counting-house ledger.

It is, therefore, suggested that the registration records of every ship give the displacement when the ship is immersed down to some definite line, which may be denominated the constructor's load line.

The assignment of the constructor's load line draught forward and aft, and the corresponding displacement, are all the statistical data that are required to be registered in addition to the details of registration already enforced under the Merchant Shipping Act of 1854, in order to determine the comparative coefficients, and put the system of practical rivalry hereby suggested into operation, as being the most effective system for inducing improvement in naval architecture.

As regards the existing system of shipping statistics and shipping registration, with reference to its affording data available for promoting shipping improvement, this Committee has to observe that, although the aggregate register tonnage of mercantile shipping appears to be a very close approximation to the aggregate weight-carrying capability of the entire mercantile navy, still, when considered in detail with reference to particular ships, it is found that the register tonnage of a ship affords no approximate criterion whatever either of the load displacement or of the weight-carrying capabilities of ships respectively; for, by reference to Appendix No. 2, it will be found that ships are frequently loaded with dead weight of cargo to the extent of double their register tonnage, and the statement (Appendix No. 2) shows the following extreme cases of weight-carrying capability with reference to register tonnage:—

Country traded with.	Vessels.	Weight of Cargo.	Register Tonnage.	Ratio of Cargo to Tonnage.
		tons.		
Morocco	34	11,576	4,075	2·8 to 1
Tunis	1	780	259	3 to 1
Bolivia	2	2,391	455	5·2 to 1

These cases appeared so remarkable, that the Committee were anxious to prosecute inquiries with reference to the build and sea performances of those particular ships, and with that view they addressed a letter to the Custom House for the purpose of identifying the vessels thus referred to; but the official fees demanded for responding to such inquiries, put it out of the power of the Committee to avail themselves to any useful purpose of the shipping statistics of Government.

Another difficulty which greatly obstructs the collecting of statistics on the sea performances of mercantile shipping, is the great number of vessels bearing the same name. In many cases, there are scores of vessels bearing the same name, thus rendering it extremely difficult to trace and scrutinize the performance of a vessel of any name with certainty as to her identity; for, in publishing the arrivals and departures of shipping in mercantile navy records, the registered number of a ship, which constitutes the only means of identification, is not generally given in connection with her name.

A further instance of the insufficiency of our present system of shipping registration as statistical data indicative of the size of the hull of steam shipping, is afforded by the statement given in Appendix No. 3, which has been deduced from a Return of the House of Commons, showing the per-centage deduction from the gross tonnage allowed for the engine rooms of steam-ships; whence we see that, without any reference whatever being made to the actual weight of the machinery, deductions are made from the gross tonnage varying from 5 per cent. to 92 per cent. of the gross measurement, the remainder only being brought to account as the registered tonnage of the ship.

In conclusion, this Committee beg to observe, that if the views thus brought before the notice of the British Association should be deemed worthy of further prosecution, and be favourably entertained by the Government, the statistics of the Post-office, as respects the constructive elements, and test trials, and subsequent sea performances of the various steam-ships employed in H. M. Mail Service, would afford a collection of statistical data which, if duly analysed and applied as herein suggested, would greatly promote the objects of this inquiry, which the British Association has thus been pleased to institute.

The Committee have the painful duty of announcing the death of one of its members, James Perry, Esq., whose personal character, practical intelligence, and public usefulness, were of such an order, that his decease may be mourned as a public loss.

(Signed)
WILLIAM FAIRBAIRN, *Chairman.*
CHARLES ATHERTON.
ANDREW HENDERSON.
HENRY WRIGHT.

The following circular was addressed to Shipowners and Shipping Companies requiring information and assistance.

APPENDIX.

I.—To Shipping Companies, Shipowners, and others connected with the Mercantile Management and Direction of Ships.

Committee on Shipping Statistics.

11 Buckingham Street, Adelphi, London, W.C.,
26th April, 1858.

GENTLEMEN,—The attention of the British Association at their late Meeting in Dublin, having been directed to the consideration of shipping statistics, the Committee of the Association came to the resolution "that the application of science to the improvement of steam-ships has been impeded by the difficulty of obtaining the necessary data from the present registration"; a Committee were thereupon appointed to inquire into this subject, which Committee beg the favour of your assistance, with a view to ascertain, from the general experience and records of shipping companies, shipowners, and others connected with the mercantile management and direction of shipping, what description of vessels has produced the best results.

In the prosecution of this inquiry, the Committee desire now, in the first place, to ascertain what have been the actual sea performances of ships, and their attention being thus directed to instances in which the performance of particular ships has been remarkable, further steps will hereafter be taken to inquire into the circumstances of such cases, and ascertain the peculiarities of proportion and type of form of the vessels which have produced such results.

With these objects in view, the Committee request the favour of your filling up the annexed form, giving an example of the quickest voyage made by each of the vessels of the line of packets under your direction, on the passage or station on which such vessels respectively may have been employed.

I am, Gentlemen,

Your very obedient servant,

HENRY WRIGHT, Hon. Sec.

By Order of the Committee.

N.B. The Committee will feel obliged by your returning the form, when filled up, to the above address, as soon as convenient; not later than the 1st of June.

Shipping Committee,

Office, 11 Buckingham Street, London, W.C.

[*It is requested that this* FORM *be filled up and returned by the* 1*st of June*, 1858.]

Name of Vessel and Registered Number.	Description of Vessel; whether Steamer or Sailing Vessel, and her Rig.	Passage referred to as an example of the performance of the Ship.			Load Draught.	Length of Vessel, as usually measured for Builders' Tonnage.	Outside Breadth of Vessel, as measured for Builders' Tonnage.	Depth of Hold.	Builders' Tonnage.	Register Tonnage.	Registered H. P.	Coals consumed on Voyage, if a Steamer.	Note: In addition to the foregoing particulars, it is requested that the Displacement of the Vessels be given at the following Draughts, if known. DISPLACEMENT.					
													When Launched		When ready for Cargo.		When immersed to Constructor's Load line.	
		Port of Departure, and Date of Departure.	Port of Arrival, and Date of Arrival.	Detention on Voyage by stoppage at intermediate Ports, or Becalmed.									Draught.	Displacement.	Draught.	Displacement.	Draught.	Displacement.
				dys. hrs.	ft. in.	ft. in.	ft. in.	ft. in.				tns. cwts.	ft. in.	tons.	ft. in.	tons.	ft. in.	tons.

Signature ____________________

Address ____________________

II.—Table showing the difference which exists between the "Register Tonnage" of Vessels and the "Tons Weight" of Cargo actually carried in the Trade and Navigation of the United Kingdom with Foreign Countries and British Possessions in 1852, 1853, 1854, and 1855, deduced from Returns of the Board of Trade.

		Imports.					Exports.				
Name of Country.	Date.	No. of Vessels.	Register Tonnage.	Tons Weight of Cargo carried.	Difference of Cargo, with reference to Tonnage.	Per Centage of Difference.	No. of Vessels.	Register Tonnage.	Tons Weight of Cargo carried.	Difference of Cargo, with reference to Tonnage.	Per Centage of Difference.
Northern Russia	1852	2022	410,875	452,291	+ 41,416	+10	1690	343,459	280,856	− 62,603	−18
	1853	3006	581,713	709,390	+127,677	+22	2291	458,811	314,930	−143,881	−31
	1854	434	72,772	89,174	+ 16,898	+23	243	36,947	2,735	− 34,212	−92
	1855	....	....	1,174	....	....	....	....	....	....	....
Southern Russia	1852	599	184,020	161,206	− 22,814	−12	117	35,280	21,788	− 13,492	−38
	1853	692	207,305	185,593	− 21,712	−10	174	50,261	14,810	− 35,451	−75
	1854	422	121,761	111,074	− 10,687	− 8	32	10,200	4,486	− 5,714	−56
	1855	....	....	22,143	....	....	....	....	....	....	....
Crimea	1855	80	27,906	905	− 27,001	−96	358	146,377	56,230	− 90,147	−61*
Sweden	1852	1013	195,819	308,355	+112,536	+57	781	142,981	82,928	− 60,053	−42
	1853	1352	256,579	399,836	+143,257	+51	1087	187,905	90,630	− 97,275	−51
	1854	1530	278,489	440,940	+162,451	+58	1113	194,296	113,199	− 81,097	−41
	1855	1551	316,568	467,160	+140,592	+14	1052	194,870	127,919	− 66,951	−34
Norway	1852	1391	216,027	218,524	+ 2,497	+ 1	1435	232,601	70,598	−162,003	−69
	1853	1888	301,717	313,158	+ 11,441	+ 3	1991	315,990	80,288	−235,702	−74
	1854	1917	299,197	314,717	+ 15,520	+ 5	2201	352,466	104,334	−248,132	−70
	1855	1585	285,402	240,124	− 45,278	−15	1676	273,857	118,206	−155,651	−56
Denmark	1852	2112	195,198	183,588	− 11,610	− 5	1305	464,131	401,578	− 62,553	−13
	1853	2324	214,742	232,301	+ 17,559	+ 8	5477	619,433	411,312	−208,121	−33
	1854	2286	202,462	223,402	+ 20,940	+10	5364	617,384	495,858	−121,526	−19
	1855	2373	229,753	247,792	+ 18,039	+ 7	4680	545,478	512,702	− 22,776	− 4

Prussia	1852	1972	299,493	409,504	+110,011	+36	1833	298,814	334,465	+ 35,651	+11
	1853	3542	573,687	776,656	+202,969	+35	2535	441,379	399,223	− 42,156	− 9
	1854	3145	540,130	682,654	+142,524	+26	2425	437,724	446,529	+ 8,805	+ 2
	1855	2907	544,268	640,960	+ 96,692	+17	2441	451,779	521,422	+ 69,643	+15
Mecklenburg	1852	234	25,207	29,629	+ 4,422	+17	132	18,778	19,062	+ 284	+ 1
	1853	266	32,869	34,536	+ 1,667	+ 5	188	29,106	32,742	+ 3,636	+12
	1854	210	27,569	27,854	+ 285	+ 1	149	21,784	23,381	+ 1,597	+ 7
	1855	203	27,693	36,569	+ 8,876	+32	176	27,763	37,487	+ 9,724	+35
Hanover	1852	767	51,180	31,375	− 19,805	−38	691	47,936	62,193	+ 14,257	+29
	1853	644	42,599	35,415	− 7,184	−16	707	52,248	65,867	+ 13,619	+26
	1854	669	45,003	37,636	− 7,367	−16	774	54,601	64,722	+ 10,121	+18
	1855	742	58,000	36,753	− 21,247	−36	851	64,681	87,936	+ 23,255	+36
Oldenburg	1852	223	13,261	8,737	− 4,524	−34	172	9,638	14,486	+ 4,848	+50
	1853	153	10,196	5,183	− 5,013	−49	133	9,545	12,141	+ 2,596	+27
	1854	144	9,568	9,211	− 357	− 3	129	9,073	11,601	+ 2,528	+27
	1855	202	19,732	10,684	− 9,048	−45*	154	14,437	19,186	+ 4,749	+32
Hanse Towns	1852	2494	502,819	79,592	−423,227	−84	2736	513,814	493,096	− 20,718	− 4
	1853	2401	475,335	115,729	−359,606	−75	2636	489,934	484,233	− 5,701	− 1
	1854	2493	519,720	165,007	−354,713	−68	2719	543,989	502,330	− 41,659	− 7
	1855	2810	627,127	125,279	−501,848	−80	2815	563,686	607,497	+ 43,811	+ 7
Holland	1852	3454	617,152	141,681	−475,471	−77	2669	417,052	321,758	− 95,294	−24
	1853	3113	644,091	147,552	−496,539	−77	2315	380,306	283,222	− 97,084	−25
	1854	3298	621,322	190,789	−430,533	−69	2749	440,659	364,419	− 76,240	−17
	1855	4127	717,955	155,634	−562,321	−78	2950	503,156	434,240	− 68,916	−13
Java and Sumatra	1852	10	4,218	4,610	+ 392	+ 9	43	19,914	14,873	− 5,041	−25
	1853	12	4,969	6,483	+ 1,514	+30	36	18,699	15,576	− 3,123	−16
	1854	24	10,436	11,467	+ 1,031	+ 9	34	15,494	11,417	− 4,077	−26
	1855	10	5,163	7,957	+ 2,794	+54	42	20,301	12,674	− 7,627	−37
Belgium	1852	1265	222,375	40,319	−182,056	−81	922	154,810	98,333	− 56,477	−36
	1853	1241	226,156	44,177	−181,079	−80	882	155,586	112,680	− 42,906	−27
	1854	1338	236,508	77,632	−158,976	−67	912	169,996	130,891	− 39,105	−23
	1855	1544	274,031	51,826	−222,205	−81	1084	179,692	112,955	− 66,737	−37

* Not including transports and munitions of war.

Name of Country.	Date.	Imports. No. of Vessels.	Imports. Register Tonnage.	Imports. Tons Weight of Cargo carried.	Imports. Difference of Cargo, with reference to Tonnage.	Imports. Per Centage of Difference.	Exports. No. of Vessels.	Exports. Register Tonnage.	Exports. Tons Weight of Cargo carried.	Exports. Difference of Cargo, with reference to Tonnage.	Exports. Per Centage of Difference.
France	1852	7867	851,128	232,969	− 618,159	−75	7478	838,628	719,283	−119,345	− 14
	1853	8884	1,014,334	249,541	− 764,793	−75	8218	920,783	812,468	−108,315	− 11
	1854	8728	1,018,298	147,632	− 870,666	−85	8185	989,093	931,930	− 57,163	− 5
	1855	9776	1,250,343	135,298	−1,115,045	−89	9569	1,172,065	1,211,385	+ 39,320	+ 3
Algeria	1852	7	779	1,194	+ 415	+53	76	13,905	16,939	+ 3,034	+ 21
	1853	29	3,723	6,276	+ 2,553	+68	112	19,374	26,298	+ 6,924	+ 35
	1854	38	6,065	9,403	+ 3,338	+55	194	25,527	24,190	− 1,337	− 5
	1855	19	3,645	1,695	− 1,950	−53	140	23,224	30,592	+ 7,368	+ 31
Isle of Bourbon	1852	....	....	....	....	....	....	....	....	....	....
	1853	....	....	....	....	....	....	....	....	....	....
	1854	1	220	230	+ 10	+ 4	2	632	657	+ 25	+ 4
	1855	....	....	....	....	....	5	1,398	154	− 1,244	− 88
Portugal, Azores, Madeira	1852	838	82,371	68,728	− 13,643	−16	1029	127,767	73,584	− 54,183	− 42
	1853	815	94,886	95,127	+ 241	+ 2	1197	171,299	126,631	− 44,668	− 26
	1854	1023	116,842	120,501	+ 3,659	+ 3	1046	150,527	103,522	− 47,005	− 31
	1855	886	110,211	118,822	+ 8,611	+ 7	920	127,988	104,029	− 23,959	− 18
Cape Verd Islands	1852	3	496	678	+ 182	+36	56	12,871	8,886	− 3,985	− 30
	1853	2	278	411	+ 133	+47	58	14,222	16,802	+ 2,580	+ 18
	1854	3	464	677	+ 213	+43	63	14,175	14,503	+ 328	+ 2
	1855	1	139	195	+ 56	+40	35	8,607	10,321	+ 1,714	+ 19
Spain and Canaries	1852	655	75,342	54,497	− 20,845	−27	1445	263,516	250,087	− 13,429	− 5
	1853	781	90,561	80,469	− 10,092	−11	1709	294,001	294,087	+ 86	+·03
	1854	1047	125,443	105,113	− 20,330	−16	1663	259,961	265,850	+ 5,889	+ 2
	1855	1372	179,030	150,837	− 28,193	−15	1387	239,519	239,491	− 28	−·01
Cuba and Porto Rico	1852	199	60,363	57,284	− 3,079	− 5	245	70,768	63,680	− 7,088	− 10
	1853	329	87,398	95,557	+ 8,159	+ 9	297	85,161	81,717	− 3,444	− 4
	1854	488	144,293	162,313	+ 17,920	+12	297	84,575	76,023	− 8,552	− 10
	1855	377	100,137	110,772	+ 10,635	+10	380	[illegible]	[illegible]	− [illegible]	− 2

Phillipine Islands	1852	9	4,823	6,079	+ 1,256	+26	10	5,178	6,833	+ 1,655	+31
	1853	6	3,324	3,719	+ 395	+11	15	7,024	9,100	+ 2,076	+29
	1854	27	14,267	21,692	+ 7,425	+52	9	4,797	4,217	− 580	−12
	1855	31	17,785	22,158	+ 4,373	+24	11	5,873	4,562	− 1,311	−22
Fernando Po	1852	....	....	2,010	....	....	....	....	6,968	....	....
	1853	....	....	5,488	....	....	....	....	9,502	....	....
	1854	14	6,820	5,230	− 1,590	−23	20	7,614	5,073	− 2,541	−33
	1855	16	6,824	6,679	− 145	− 2	17	6,759	5,234	− 1,525	−22
Sardinia	1852	53	14,068	2,181	− 11,887	−84	303	65,186	73,477	+ 8,291	+12
	1853	51	15,863	2,501	− 13,362	−84	437	96,399	112,246	+ 15,847	+16
	1854	180	48,528	3,497	− 45,031	−92	467	102,491	118,429	+ 15,938	+15
	1855	105	32,085	11,157	− 20,928	−65	320	97,027	112,352	+ 15,325	+15
Tuscany	1852	110	18,483	17,706	− 777	− 4	99	19,260	23,592	+ 4,332	+22
	1853	139	24,776	25,645	+ 869	+ 3	124	21,695	28,154	+ 6,459	+29
	1854	172	30,672	26,141	− 4,531	−14	119	19,881	25,074	+ 5,193	+26
	1855	206	37,897	28,805	− 9,092	−24	87	13,676	20,687	+ 7,011	+51
Papal States	1852	43	8,157	7,383	− 774	− 9	49	8,292	9,782	+ 1,490	+18
	1853	45	7,726	10,419	+ 2,693	+34	53	9,587	11,229	+ 1,642	+17
	1854	20	3,674	2,004	− 1,670	−45	37	6,542	8,085	+ 1,543	+23
	1855	27	5,102	6,760	+ 1,658	+32	39	6,758	11,080	+ 4,322	+64
Naples	1852	404	54,985	69,575	+ 14,590	+26	371	64,327	70,370	+ 6,403	+ 9
	1853	371	55,079	72,822	+ 17,743	+32	359	64,695	72,326	+ 7,631	+11
	1854	509	81,729	104,809	+ 23,080	+28	360	63,181	72,531	+ 9,350	+14
	1855	411	71,987	82,006	+ 10,019	+13	404	73,422	93,194	+ 19,772	+27
Austria..............	1852	117	28,900	28,439	− 461	− 1	357	95,529	97,744	+ 2,215	+ 2
	1853	147	34,070	30,238	− 3,832	−11	344	83,463	86,115	+ 2,652	+ 3
	1854	178	48,396	28,774	− 19,622	−40	308	76,034	94,127	+ 18,093	+23
	1855	164	45,126	42,495	− 2,631	− 5	193	65,877	78,813	+ 12,936	+19
Greece	1852	53	7,470	6,707	− 763	−10	78	17,021	10,014	− 7,007	−41
	1853	91	15,220	11,368	− 3,752	−24	86	21,425	12,263	− 9,162	−42
	1854	58	9,361	7,055	− 2,306	−24	101	22,679	29,605	+ 6,926	+30
	1855	178	39,919	41,901	+ 1,982	+ 4	78	22,716	34,658	+ 11,942	+52

II.—Table showing the difference which exists between the "Register Tonnage" of Vessels and the "Tons Weight" of Cargo actually carried in the Trade and Navigation of the United Kingdom with Foreign Countries and British Possessions in 1852, 1853, 1854, and 1855, deduced from Returns of the Board of Trade.

		Imports.					Exports.				
Name of Country.	Date.	No. of Vessels.	Register Tonnage.	Tons Weight of Cargo carried.	Difference of Cargo, with reference to Tonnage.	Per Centage of Difference.	No. of Vessels.	Register Tonnage.	Tons Weight of Cargo carried.	Difference of Cargo, with reference to Tonnage.	Per Centage of Difference.
Northern Russia	1852	2022	410,875	452,291	+ 41,416	+10	1690	343,459	280,856	− 62,603	−18
	1853	3006	581,713	709,390	+127,677	+22	2291	458,811	314,930	−143,881	−31
	1854	434	72,772	89,174	+ 16,898	+23	243	36,947	2,735	− 34,212	−92
	1855	....	....	1,174	....	....	....	....	....	....	....
Southern Russia	1852	599	184,020	161,206	− 22,814	−12	117	35,280	21,788	− 13,492	−38
	1853	692	207,305	185,593	− 21,712	−10	174	50,261	14,810	− 35,451	−75
	1854	422	121,761	111,074	− 10,687	− 8	32	10,200	4,486	− 5,714	−56
	1855	....	....	22,143	....	....	....	....	....	....	....
Crimea	1855	80	27,906	905	− 27,001	−96	358	146,377	56,230	− 90,147	−61*
Sweden	1852	1013	195,819	308,355	+112,536	+57	781	142,981	82,928	− 60,053	−42
	1853	1352	256,579	399,836	+143,257	+51	1087	187,905	90,630	− 97,275	−51
	1854	1530	278,489	440,940	+162,451	+58	1113	194,296	113,199	− 81,097	−41
	1855	1551	316,568	467,160	+140,592	+14	1052	194,870	127,919	− 66,951	−34
Norway	1852	1391	216,027	218,524	+ 2,497	+ 1	1435	232,601	70,598	−162,003	−69
	1853	1888	301,717	313,158	+ 11,441	+ 3	1991	315,990	80,288	−235,702	−74
	1854	1917	299,197	314,717	+ 15,520	+ 5	2201	352,466	104,334	−248,132	−70
	1855	1585	285,402	240,124	− 45,278	−15	1676	273,857	118,206	−155,651	−56
Denmark	1852	2112	195,198	183,588	− 11,610	− 5	1305	464,131	401,578	− 62,553	−13
	1853	2324	214,742	232,301	+ 17,559	+ 8	5477	619,433	411,312	−208,121	−33
	1854	2286	202,462	223,402	+ 20,940	+10	5364	617,384	495,858	−121,526	−19
	1855	2373	229,753	247,792	+ 18,039	+ 7	4680	545,478	512,702	− 22,776	− 4

Prussia	1852	1972	299,493	409,504	+110,011	+36	1833	298,814	334,465	+ 35,651	+11
	1853	3542	573,687	776,656	+202,969	+35	2535	441,379	399,223	− 42,156	− 9
	1854	3145	540,130	682,654	+142,524	+26	2425	437,724	446,529	+ 8,805	+ 2
	1855	2907	544,268	640,960	+ 96,692	+17	2441	451,779	521,422	+ 69,643	+15
Mecklenburg	1852	234	25,207	29,629	+ 4,422	+17	132	18,778	19,062	+ 284	+ 1
	1853	266	32,869	34,536	+ 1,667	+ 5	188	29,106	32,742	+ 3,636	+12
	1854	210	27,569	27,854	+ 285	+ 1	149	21,784	23,381	+ 1,597	+ 7
	1855	203	27,693	36,569	+ 8,876	+32	176	27,763	37,487	+ 9,724	+35
Hanover	1852	767	51,180	31,375	− 19,805	−38	691	47,936	62,193	+ 14,257	+29
	1853	644	42,599	35,415	− 7,184	−16	707	52,248	65,867	+ 13,619	+26
	1854	669	45,003	37,636	− 7,367	−16	774	54,601	64,722	+ 10,121	+18
	1855	742	58,000	36,753	− 21,247	−36	851	64,681	87,936	+ 23,255	+36
Oldenburg	1852	223	13,261	8,737	− 4,524	−34	172	9,638	14,486	+ 4,848	+50
	1853	153	10,196	5,183	− 5,013	−49	133	9,545	12,141	+ 2,596	+27
	1854	144	9,568	9,211	− 357	− 3	129	9,073	11,601	+ 2,528	+27
	1855	202	19,732	10,684	− 9,048	−45	154	14,437	19,186	+ 4,749	+32
Hanse Towns	1852	2494	502,819	79,592	−423,227	−84	2736	513,814	493,096	− 20,718	− 4
	1853	2401	475,335	115,729	−359,606	−75	2636	489,934	484,233	− 5,701	− 1
	1854	2493	519,720	165,007	−354,713	−68	2719	543,989	502,330	− 41,659	− 7
	1855	2810	627,127	125,279	−501,848	−80	2815	563,686	607,497	+ 43,811	+ 7
Holland	1852	3454	617,152	141,681	−475,471	−77	2669	417,052	321,758	− 95,294	−24
	1853	3113	644,091	147,552	−496,539	−77	2315	380,306	283,222	− 97,084	−25
	1854	3298	621,322	190,789	−430,533	−69	2749	440,659	364,419	− 76,240	−17
	1855	4127	717,955	155,634	−562,321	−78	2950	503,156	434,240	− 68,916	−13
Java and Sumatra	1852	10	4,218	4,610	+ 392	+ 9	43	19,914	14,873	− 5,041	−25
	1853	12	4,969	6,483	+ 1,514	+30	36	18,699	15,576	− 3,123	−16
	1854	24	10,436	11,467	+ 1,031	+ 9	34	15,494	11,417	− 4,077	−26
	1855	10	5,163	7,957	+ 2,794	+54	42	20,301	12,674	− 7,627	−37
Belgium	1852	1265	222,375	40,319	−182,056	−81	922	154,810	98,333	− 56,477	−36
	1853	1241	226,156	44,177	−181,079	−80	882	155,586	112,680	− 42,906	−27
	1854	1338	236,508	77,632	−158,976	−67	912	169,996	130,891	− 39,105	−23
	1855	1544	274,031	51,826	−222,205	−81	1084	179,692	112,955	− 66,737	−37

* Not including transports and munitions of war.

Name of Country.	Date.	Imports. No. of Vessels.	Register Tonnage.	Tons Weight of Cargo carried.	Difference of Cargo, with reference to Tonnage.	Per Centage of Difference.	Exports. No. of Vessels.	Register Tonnage.	Tons Weight of Cargo carried.	Difference of Cargo, with reference to Tonnage.	Per Centage of Difference.
France	1852	7867	851,128	232,969	− 618,159	−75	7478	838,628	719,283	−119,345	− 14
	1853	8884	1,014,334	249,541	− 764,793	−75	8218	920,783	812,468	−108,315	− 11
	1854	8728	1,018,298	147,632	− 870,666	−85	8185	989,093	931,930	− 57,163	− 5
	1855	9776	1,250,343	135,298	−1,115,045	−89	9569	1,172,065	1,211,385	+ 39,320	+ 3
Algeria	1852	7	779	1,194	+ 415	+53	76	13,905	16,939	+ 3,034	+ 21
	1853	29	3,723	6,276	+ 2,553	+68	112	19,374	26,298	+ 6,924	+ 35
	1854	38	6,065	9,403	+ 3,338	+55	194	25,527	24,190	− 1,337	− 5
	1855	19	3,645	1,695	− 1,950	−53	140	23,224	30,592	+ 7,368	+ 31
Isle of Bourbon	1852	....	....	....	....	....	....	....	....	....	....
	1853	....	....	....	....	....	....	....	....	....	....
	1854	1	220	230	+ 10	+ 4	2	632	657	+ 25	+ 4
	1855	....	....	....	....	....	5	1,398	154	− 1,244	− 88
Portugal, Azores, Madeira	1852	838	82,371	68,728	− 13,643	−16	1029	127,767	73,584	− 54,183	− 42
	1853	815	94,886	95,127	+ 241	+ 2	1297	171,299	126,631	− 44,668	− 26
	1854	1023	116,842	120,501	+ 3,659	+ 3	1046	150,527	103,522	− 47,005	− 31
	1855	886	110,211	118,822	+ 8,611	+ 7	920	127,988	104,029	− 23,959	− 18
Cape Verd Islands	1852	3	496	678	+ 182	+36	56	12,871	8,886	− 3,985	− 30
	1853	2	278	411	+ 133	+47	58	14,222	16,802	+ 2,580	+ 18
	1854	3	464	677	+ 213	+43	63	14,175	14,503	+ 328	+ 2
	1855	1	139	195	+ 56	+40	35	8,607	10,321	+ 1,714	+ 19
Spain and Canaries	1852	655	75,342	54,497	− 20,845	−27	1445	263,516	250,087	− 13,429	− 5
	1853	781	90,561	80,469	− 10,092	−11	1709	294,001	294,087	+ 86	+·03
	1854	1047	125,443	105,113	− 20,330	−16	1663	259,961	265,850	+ 5,889	+ 2
	1855	1372	179,030	150,837	− 28,193	−15	1387	239,519	239,491	− 28	−·01
Cuba and Porto Rico	1852	199	60,363	57,284	− 3,079	− 5	245	70,768	63,680	− 7,088	− 10
	1853	329	87,398	95,557	+ 8,159	+ 9	297	85,161	81,717	− 3,444	− 4
	1854	488	144,393	162,313	+ 17,920	+12	297	84,575	76,023	− 8,552	− 10
	1855	377	100,137	110,772	+ 10,635	+10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Phillipine Islands	1852	9	4,823	6,079	+ 1,256	+26	10	5,178	6,833	+ 1,655	+31
	1853	6	3,324	3,719	+ 395	+11	15	7,024	9,100	+ 2,076	+29
	1854	27	14,267	21,692	+ 7,425	+52	9	4,797	4,417	− 380	−12
	1855	31	17,785	22,158	+ 4,373	+24	11	5,873	4,562	− 1,311	−22
Fernando Po	1852	....	....	2,010	....	....	....	....	6,968	....	....
	1853	....	....	5,488	....	....	....	....	9,502	....	....
	1854	14	6,820	5,230	− 1,590	−23	20	7,614	5,073	− 2,541	−33
	1855	16	6,824	6,679	− 145	− 2	17	6,759	5,234	− 1,525	−22
Sardinia	1852	53	14,068	2,181	− 11,887	−84	303	65,186	73,477	+ 8,291	+12
	1853	51	15,863	2,501	− 13,362	−84	437	96,399	112,246	+ 15,847	+16
	1854	180	48,528	3,497	− 45,031	−92	467	102,491	118,429	+ 15,938	+15
	1855	105	32,085	11,157	− 20,928	−65	320	97,027	112,352	+ 15,325	+15
Tuscany	1852	110	18,483	17,706	− 777	− 4	99	19,260	23,592	+ 4,332	+22
	1853	139	24,776	25,645	+ 869	+ 3	124	21,695	28,154	+ 6,459	+29
	1854	172	30,672	26,141	− 4,531	−14	119	19,881	25,074	+ 5,193	+26
	1855	206	37,897	28,805	− 9,092	−24	87	13,676	20,687	+ 7,011	+51
Papal States	1852	43	8,157	7,383	− 774	− 9	49	8,292	9,782	+ 1,490	+18
	1853	45	7,726	10,419	+ 2,693	+34	53	9,587	11,229	+ 1,642	+17
	1854	20	3,674	2,004	− 1,670	−45	37	6,542	8,085	+ 1,543	+23
	1855	27	5,102	6,760	+ 1,658	+32	39	6,758	11,080	+ 4,322	+64
Naples	1852	404	54,985	69,575	+ 14,590	+26	371	64,327	70,370	+ 6,403	+ 9
	1853	371	55,079	72,822	+ 17,743	+32	359	64,695	72,326	+ 7,631	+11
	1854	509	81,729	104,809	+ 23,080	+28	360	63,181	72,531	+ 9,350	+14
	1855	411	71,987	82,006	+ 10,019	+13	404	73,422	93,194	+ 19,772	+27
Austria.............	1852	117	28,900	28,439	− 461	− 1	357	95,529	97,744	+ 2,215	+ 2
	1853	147	34,070	30,238	− 3,832	−11	344	83,463	86,115	+ 2,652	+ 3
	1854	178	48,396	28,774	− 19,622	−40	308	76,034	94,127	+ 18,093	+23
	1855	164	45,126	42,495	− 2,631	− 5	193	65,877	78,813	+ 12,936	+19
Greece..............	1852	53	7,470	6,707	− 763	−10	78	17,021	10,014	− 7,007	−41
	1853	91	15,120	11,368	− 3,752	−24	86	21,425	12,263	− 9,162	−42
	1854	58	9,361	7,055	− 2,306	−24	101	22,679	29,605	+ 6,926	+30
	1855	178	39,919	41,901	+ 1,982	+ 4	78	22,716	34,658	+ 11,942	+52

Name of Country.	Date.	Imports. No. of Vessels.	Imports. Register Tonnage.	Imports. Tons Weight of Cargo carried.	Imports. Difference of Cargo, with reference to Tonnage.	Imports. Per Centage of Difference.	Exports. No. of Vessels.	Exports. Register Tonnage.	Exports. Tons Weight of Cargo carried.	Exports. Difference of Cargo, with reference to Tonnage.	Exports. Per Centage of Difference.
Turkey	1852	335	76,098	73,816	− 2,282	− 3	566	146,976	94,825	− 52,151	−35
	1853	600	155,973	184,952	+ 28,979	+18	876	237,860	102,836	−135,024	−56
	1854	429	123,444	104,893	− 18,551	−15	1038	356,558	301,580	− 44,978	−12
	1855	439	131,336	84,453	− 46,883	−35	1718	559,295	541,417	− 17,878	−
Wallachia and Moldavia	1852	565	105,942	143,385	+ 37,443	+35	157	25,669	14,878	− 10,791	−42
	1853	557	97,706	133,849	+ 36,143	+37	123	19,047	8,301	− 10,746	−56
	1854	142	21,715	29,872	+ 8,157	+37	6	666	1,017	+ 351	+52
	1855	11	2,683	4,642	+ 1,959	+73	5	606	590	− 16	− 2
Syria and Palestine	1852	27	5,408	5,599	+ 191	+ 3	71	14,600	8,038	− 6,562	−45
	1853	45	9,491	11,223	+ 1,732	+18	51	10,997	9,730	− 1,267	−11
	1854	21	4,693	4,896	+ 203	+ 4	42	9,601	9,226	− 375	− 3
	1855	24	5,445	3,119	− 2,326	−42	90	20,046	16,726	− 3,320	−16
Egypt	1852	557	174,400	179,860	+ 5,460	+ 3	257	79,359	63,679	− 15,680	−19
	1853	451	152,936	156,694	+ 3,758	+ 2	170	71,237	31,412	− 39,825	−55
	1854	400	133,053	141,458	+ 8,405	+ 6	258	94,208	77,868	− 16,340	−17
	1855	468	153,418	175,043	+ 21,625	+14	191	72,196	58,057	− 14,139	−19
Tripoli	1852	....	....	....	....	....	....	....	....	....	....
	1853	....	....	....	....	....	....	....	....	....	....
	1854	....	....	13	....	....	....	....	....	....	....
	1855	....	....	127	....	....	....	....	....	....	....
Tunis	1852	....	....	100	....	....	1	259	780	+ 521	+201*
	1853	....	....	106	....	....	4	728	858	+ 130	+17
	1854	1	164	226	+ 62	+37	9	1,542	1,938	+ 396	+24
	1855	2	224	....	....	....	9	1,492	2,269	+ 777	+52
Morocco	1852	39	4,357	3,349	− 1,008	−23	25	3,375	1,716	− 1,659	−49
	1853	76	8,448	8,300	− 148	− 1	37	5,511	1,770	− 3,741	−67
	1854	110	12,720	14,664	+ 1,944	+15	34	4,075	11,576	+ 7,501	+184
	1855	142	16,720	19,827	+ 3,107	+19	45	5,719	[illegible]	[illegible]	[illegible]

United States	1852	1382	1,101,023	728,441	−372,582	−33	2026	1,442,076	1,193,216	−248,860	−17
	1853	1436	1,088,009	797,747	−290,262	−26	2157	1,541,278	1,347,918	−193,360	−12
	1854	1502	1,291,532	956,516	−335,016	−26	1972	1,486,551	1,225,867	−260,684	−17
	1855	1171	1,096,379	604,554	−491,825	−45	1498	1,334,237	1,021,418	−312,819	−23
Mexico	1852	21	13,781	6,335	− 7,446	−54	43	16,787	14,039	− 2,748	−16
	1853	24	7,406	9,438	+ 2,032	+27	50	12,724	9,821	− 2,903	−22
	1854	21	6,360	9,854	+ 3,494	+54	33	7,041	6,521	− 520	− 7
	1855	38	8,101	9,582	+ 1,481	+18	47	10,656	8,710	− 1,946	−18
Central America	1852	50	15,354	5,772	− 9,582	−62	26	9,300	2,418	− 6,882	−74
	1853	34	7,136	4,213	− 2,923	−40	13	3,075	1,938	− 2,137	−69
	1854	46	9,690	2,540	− 7,150	−73	10	4,012	1,611	− 2,401	−59
	1855	19	5,005	2,452	− 2,553	−51	17	5,342	2,586	− 2,756	−57
Hayti	1852	55	11,537	12,583	+ 1,046	+ 9	45	7,988	2,951	− 5,037	−63
	1853	47	10,630	12,226	+ 1,596	+15	29	4,455	1,592	− 2,863	−54
	1854	45	9,405	10,188	+ 783	+ 8	40	7,201	2,331	− 4,870	−66
	1855	31	7,163	7,654	+ 491	+ 6	30	4,987	1,493	− 3,494	−70
Foreign West Indies	1852	5	996	434	− 562	−56	209	65,878	55,037	− 10,841	−16
	1853	39	44,899	796	− 44,103	−98	246	101,916	71,631	− 30,285	−29
	1854	53	48,754	2,773	− 46,021	−94	249	95,217	57,961	− 37,256	−39
	1855	53	50,775	3,583	− 47,192	−92	231	96,517	56,859	− 39,658	−41
New Granada	1852	39	8,018	6,134	− 1,884	−23	80	48,105	36,742	− 11,363	−24
	1853	27	5,973	4,716	− 1,257	−21	39	13,100	17,073	+ 3,973	+30
	1854	40	9,094	9,314	+ 220	+ 2	21	6,526	6,099	− 427	− 6
	1855	42	9,614	8,979	− 635	− 6	27	6,636	6,789	+ 153	+ 2
Venezuela	1852	8	1,429	1,022	− 407	−28	32	5,997	3,213	− 2,784	−46
	1853	9	1,626	1,219	− 407	−25	27	5,106	2,710	− 2,396	−46
	1854	13	2,676	2,240	− 436	−16	39	6,885	3,292	− 3,592	−52
	1855	11	2,747	3,432	+ 685	+25	35	6,250	3,697	− 2,553	−40
Brazil	1852	247	71,578	43,623	− 27,955	−39	435	115,024	102,104	− 12,920	−11
	1853	318	88,455	63,865	− 24,590	−27	422	122,493	105,005	− 17,488	−14
	1854	273	86,077	61,858	− 24,219	−28	539	161,373	157,408	− 3,965	− 2
	1855	305	85,037	62,450	− 22,587	−26	446	144,483	127,125	− 17,358	−12

* *Queen of the Tyne*, sailing vessel. Registered number, 3443.

Name of Country.	Date.	Imports. No. of Vessels.	Imports. Register Tonnage.	Imports. Tons Weight of Cargo carried.	Imports. Difference of Cargo, with reference to Tonnage.	Imports. Per Centage of Difference.	Exports. No. of Vessels.	Exports. Register Tonnage.	Exports. Tons Weight of Cargo carried.	Exports. Difference of Cargo, with reference to Tonnage.	Exports. Per Centage of Difference.
Monte Video	1852	34	6,977	7,005	+ 28	+·4	42	8,687	11,023	+ 2,336	+26
	1853	57	12,288	12,653	+ 365	+ 3	30	9,603	14,058	+ 4,455	+46
	1854	40	9,091	10,232	+ 1,141	+12	46	12,376	12,885	+ 509	+ 4
	1855	69	14,816	17,228	+ 2,412	+16	34	9,723	14,897	+ 5,174	+53
Buenos Ayres	1852	124	28,047	30,033	+ 1,986	+ 7	92	20,043	15,145	− 4,898	−24
	1853	97	21,230	31,330	+ 100	+·4	67	14,890	8 705	− 6,185	−41
	1854	122	26,967	30,224	+ 3,257	+12	117	26,802	24,270	− 2,532	− 9
	1855	112	25,182	25,568	+ 386	+ 1	88	22,544	17,523	− 5,021	−22
Patagonia	1852	23	5,455	7,282	+ 1,827	+33	....	....	....	....	....
	1853	6	1,758	2,245	+ 487	+27	....	....	....	....	....
	1854	1	368	431	+ 63	+17	....	....	....	....	....
	1855	2	558	....	....	....	....	....	....	....	....
Chili	1852	74	22,750	23,378	+ 620	+ 2	142	55,545	51,253	− 4,292	− 7
	1853	95	30,974	30,057	− 917	− 3	138	57,953	59,267	+ 1,314	+ 2
	1854	83	27,985	34,509	+ 6,524	+23	191	64,846	66,925	+ 2,079	+ 3
	1855	99	31,851	41,332	+ 9,481	+29	135	60,434	60,919	+ 485	+·8
Bolivia	1852	12	4,664	6,519	+ 1,855	+39	2	280	....	....	....
	1853	1	736	1,659	+ 923	+125*	1	299	....	....	....
	1854	....	....	834	....	....	....	....	....	....	....
	1855	2	455	2,391	+ 1,936	+425†	....	....	....	....	....
Peru	1852	166	78,384	102,236	+ 23,852	+30	69	34,679	35,142	+ 463	+ 1
	1853	210	103,873	125,899	+ 22,026	+21	71	29,062	23,313	− 5,749	−19
	1854	378	191,044	243,934	+ 52,890	+27	104	60,898	32,717	− 28,181	−46
	1855	371	219,215	274,199	+ 54,984	+25	89	47,410	32,300	− 15,110	−31
Ecuador	1852	....	....	138	....	....	2	849	47	− 802	−94
	1853	2	565	270	− 295	52	5	1,325	373	− 952	−71
	1854	2	464	573	+ 109	23	2	509	161	− 348	−68
	1855	2	720	907	+ 187	26	1	261	184	− 77	−29

China (including Hong Kong)	1852	118	63,997	33,592	− 30,405	−47	99	47,097	37,929	− 9,168	−19
	1853	118	64,928	33,289	− 31,639	−48	114	56,028	50,283	− 5,745	−12
	1854	135	79,084	40,952	− 38,132	−48	64	34,814	28,536	− 6,278	−18
	1855	133	83,211	40,785	− 42,426	−50	96	53,929	45,506	− 8,423	−15
Borneo and Indian Archipelago	1852	....	....	....	....	....	1	532	743	+ 211	+39
	1853	....	....	....	....	....	5	1,722	3,241	+ 1,519	+88
	1854	....	....	....	....	....	....	....	....	....	....
	1855	....	....	....	....	....	....	....	....	....	....
Birman Empire	1852	....	....	....	....	....	....	....	....	....	....
	1853	....	....	....	....	....	5	2,675	1,871	− 804	−30
	1854	....	....	434	....	....	9	3,561	27	− 3,534	−99
	1855	....	....	....	....	....	8	3,125	23	− 3,102	−99
Persian Gulf	1852	....	....	....	....	....	1	162	....	....	....
	1853	....	....	....	....	....	2	337	209	− 128	−35
	1854	....	....	....	....	....	....	....	....	....	....
	1855	....	....	....	....	....	....	....	....	....	....
Red Sea	1852	....	....	....	....	....	5	2,312	2,466	+ 154	+ 6
	1853	....	....	....	....	....	4	1,115	766	− 349	−31
	1854	....	....	....	....	....	3	858	1,843	+ 985	+114
	1855	....	....	....	....	....	7	2,887	3,924	+ 1,037	+36
West Coast of Africa (Foreign Possessions)	1852	108	32,073	28,752	− 3,321	−10	101	29,137	28,679	− 458	− 1
	1853	88	25,817	25,047	− 770	− 3	153	51,618	54,171	+ 2,553	+ 5
	1854	128	36,858	33,665	− 3,193	− 8	150	46,266	52,352	+ 6,086	+13
	1855	126	37,296	36,011	− 1,285	− 3	148	46,823	54,727	+ 7,904	+17
East Coast of Africa	1852	4	1,471	1,438	− 33	− 2	1	262	87	− 175	−66
	1853	....	....	....	....	....	1	178	113	− 65	−36
	1854	....	....	....	....	....	2	626	768	+ 142	+22
	1855	1	174	107	− 67	−39	2	406	105	− 301	−74

* *Montrose*, sailing vessel. Registered number, 25,023.

† *Tallentire*, sailing vessel, 261 tons register. Registered number, 25,629; and *Alice of Nantes*, Foreign sailing vessel, 194 tons register.

Name of Country.	Date.	Imports. No. of Vessels.	Imports. Register Tonnage.	Imports. Tons Weight of Cargo carried.	Imports. Difference of Cargo, with reference to Tonnage.	Imports. Per Centage of Difference.	Exports. No. of Vessels.	Exports. Register Tonnage.	Exports. Tons Weight of Cargo carried.	Exports. Difference of Cargo, with reference to Tonnage.	Exports. Per Centage of Difference.
South Sea Islands	1852	....	....	....	....	....	6	1,339	529	− 810	−60
	1853	1	181	70	− 111	−61	3	729	671	− 58	− 8
	1854	....	....	....	....	....	6	2,267	2,409	+ 142	+ 6
	1855	1	296	130	− 166	−56	4	1,396	1,370	− 26	− 2
Greenland and South Sea Fisheries	1852	54	15,009	3,783	− 11,226	−74	54	15,058	100	− 14,958	−99
	1853	63	16,226	4,347	− 11,879	−73	67	16,982	51	− 16,931	−99
	1854	52	14,596	2,180	− 12,416	−85	55	14,702	....	....	....
	1855	58	16,763	3,987	− 12,776	−76	56	15,189	....	....	....
Baltic Fleet	1854	7	5,161	....	....	....	16	15,380	....	....	....
	1855	11	2,339	....	....	....	3	647	....	....	....
Alacrane Islands	1852	....	....	....	....	....	....	....	....	....	....
	1853	....	....	....	....	....	....	....	....	....	....
	1854	....	....	....	....	....	....	....	....	....	....
	1855	1	444	....	....	....	....	....	....	....	....
Arctic Regions........	1852	....	....	....	....	....	....	....	....	....	....
	1853	....	....	....	....	....	2	574	....	....	....
	1854	....	....	....	....	....	....	....	....	....	....
	1855	....	....	....	....	....	....	....	....	....	....
Channel Islands	1852	1821	179,607	121,999	− 57,608	−32	1560	137,881	75,717	− 62,164	−45
	1853	1890	176,850	131,132	− 44,618	−25	1486	128,546	71,557	− 56,989	−44
	1854	2083	191,688	134,508	− 57,180	−29	1570	137,206	79,286	− 57,920	−42
	1855	1922	166,229	112,719	− 53,510	−32	1442	118,920	76,976	− 41,944	−35
Heligoland	1852	1	173	19	− 154	−89	1	53	....	....	....
	1853	1	30	....	....	....	2	64	....	....	....
	1854	....	....	....	....	....	1	36	24	− 12	−33
	1855	10	2,113	....	....	....	7	1,554	1,310	− 244	−15

Gibraltar	1852	41	13,594	411	− 13,183	−97	213	39,197	28,808	− 10,389	−26
	1853	63	18,223	2,150	− 16,073	−88	280	49,606	42,711	− 6,895	−13
	1854	66	20,456	1,220	− 19,236	−94	342	59,624	56,465	− 3,159	− 5
	1855	87	27,425	1,859	− 25,566	−93	445	82,885	97,139	+ 14,254	+17
Malta	1852	82	12,727	14,908	+ 2,181	+17	225	56,813	56,218	− 595	− 1
	1853	54	9,873	12,566	+ 2,693	+27	344	87,013	92,727	+ 5,714	+ 6
	1854	119	32,822	7,481	− 25,341	−77	678	199,067	168,505	− 30,562	−19
	1855	122	41,609	3,741	− 37,868	−90	696	228,918	265,525	+ 36,607	+16
Ionian Islands.........	1852	36	4,555	4,756	+ 201	+ 4	61	13,494	14,047	+ 553	+ 4
	1853	48	6,985	7,343	+ 358	+ 5	71	16,819	17,873	+ 1,054	+ 6
	1854	33	4,999	4,685	− 314	− 6	72	17,741	21,459	+ 3,718	+21
	1855	25	4,359	3,043	− 1,316	−30	42	13,775	17,825	+ 4,050	+29
N. American Provinces..	1852	2219	951,756	1,255,277	+ 303,521	+31	1351	522,870	247,897	− 274,973	−52
	1853	2324	1,002,990	1,330,933	+ 327,943	+32	1423	568,596	321,106	− 247,490	−43
	1854	2812	1,262,016	1,463,016	+ 201,000	+13	1579	657,828	398,877	− 258,951	−39
	1855	1567	795,023	1,049,354	+ 254,331	+31	861	391,704	197,196	− 194,508	−49
W. Indies and Honduras	1852	896	255,263	264,699	+ 9,436	+ 3	797	232,055	160,300	− 71,755	−30
	1853	733	194,406	217,716	+ 13,310	+ 6	657	180,350	139,376	− 40,974	−22
	1854	905	255,057	277,938	+ 22,881	+ 9	795	230,490	163,694	− 66,796	−28
	1855	736	222,329	247,049	+ 24,720	+11	654	204,118	149,018	− 55,100	−27
Falkland Islands	1852	1	817	....	....	....	5	1,060	180	− 880	−83
	1853	2	562	181	− 381	−67	4	1,468	1,150	− 318	−21
	1854	3	699	651	− 48	− 7	3	380	896	+ 516	+15
	1855	....	....	....	....	....	....	....	403	....	....
Australia & New Zealand	1852	159	75,275	48,767	− 26,508	−35	586	346,010	96,716	− 249,284	−72
	1853	177	103,611	39,147	− 64,464	−62	1225	565,252	313,197	− 252,055	−44
	1854	177	118,132	39,667	− 78,465	−64	884	538,192	268,655	− 269,537	−50
	1855	161	104,120	41,028	− 63,092	−60	465	350,751	168,111	− 182,640	−52
E. Indies and Singapore	1852	499	294,824	304,472	+ 9,648	+ 3	430	249,627	178,790	− 70,837	−28
	1853	549	347,336	339,293	− 8,043	− 2	455	276,621	221,041	− 55,580	−20
	1854	577	356,247	348,034	− 8,213	− 2	481	292,934	226,476	− 66,458	−22
	1855	637	431,178	437,874	+ 6,696	+ 1	719	510,171	370,532	− 140,639	−27

Name of Country.	Date.	Imports. No. of Vessels.	Imports. Register Tonnage.	Imports. Tons Weight of Cargo carried.	Imports. Difference of Cargo, with reference to Tonnage.	Imports. Per Centage of Difference.	Exports. No. of Vessels.	Exports. Register Tonnage.	Exports. Tons Weight of Cargo carried.	Exports. Difference of Cargo, with reference to Tonnage.	Exports. Per Centage of Difference.
Ceylon	1852	50	21,015	20,979	− 36	−·17	69	28,780	26,625	− 2,155	− 7
	1853	54	20,994	22,139	+ 1,145	+ 5	66	27,216	27,113	− 103	−·37
	1854	73	31,522	31,218	− 304	−·9	78	31,418	35,317	+ 3,899	+ 12
	1855	60	27,514	26,471	− 1,045	− 3	36	30,302	21,538	− 8,764	− 28
Aden	1852	1	1,176	....	....	....	48	26,445	34,977	+ 8,532	+ 32
	1853	1	202	209	+ 7	+ 3	40	24,179	28,510	+ 4,331	+ 17
	1854	....	....	....	....	....	43	25,879	32,465	+ 6,586	+ 25
	1855	....	....	....	....	....	53	23,668	36,871	+ 13,203	+ 55
Mauritius	1852	138	44,708	56,215	+ 11,507	+ 25	42	17,214	11,815	− 5,399	− 31
	1853	140	49,745	62,919	+ 13,174	+ 26	57	23,905	23,998	+ 93	+·03
	1854	197	67,330	83,895	+ 16,565	+ 24	49	19,799	14,280	− 5,519	− 27
	1855	156	56,024	68,875	+ 12,851	+ 22	62	24,626	13,820	− 10,806	− 43
Cape of Good Hope	1852	66	17,249	11,933	− 5,316	− 30	157	45,847	42,682	− 3,165	− 6
	1853	39	10,416	5,488	− 4,928	− 47	183	51,411	50,322	− 1,089	− 2
	1854	51	13,990	9,745	− 4,245	− 30	77	20,531	21,052	+ 521	+ 2
	1855	69	17,228	11,311	− 5,917	− 34	106	30,782	32,121	+ 1,339	+ 4
West Coast of Africa	1852	77	20,423	13,416	− 7,007	− 34	80	20,258	12,140	− 8,118	− 40
	1853	72	23,559	10,905	− 12,654	− 53	83	25,995	12,938	− 13,057	− 50
	1854	53	15,114	10,986	− 4,128	− 27	58	15,195	11,498	− 3,697	− 24
	1855	50	13,953	12,341	− 1,612	− 11	71	18,870	14,980	− 3,890	− 20
St. Helena and Ascension	1852	3	1,028	1,077	+ 49	+ 4	23	6,267	4,919	− 1,348	− 21
	1853	4	1,024	7	− 1,017	− 99	23	7,211	6,655	− 556	− 7
	1854	2	190	246	+ 56	+ 29	14	3,718	2,867	− 851	− 22
	1855	2	340	307	− 33	− 8	14	3,090	1,573	− 1,517	− 49
Settlements of Hudson's Bay Company	1852	....	....	1,221	....	....	....	....	1,012	....	....
	1853	....	....	1,095	....	....	....	....	904	....	....
	1854	....	....	1,346	....	....	....	....	1,153	....	....
	1855	....	....	1,206	....	....	....	....	958	....	....

III.—Statement abstracted from a Return of the House of Commons, showing the total number of Steam Vessels Registered in the United Kingdom on or before the 1st of January, 1855, and the Per-centage of Deduction from Gross Tonnage, allowed for Engine-room, distinguishing whether Wood or Iron Paddle, and Wood or Iron Screw Vessels.

No. of Iron Paddle Vessels.	Per-centage of Deduction from Gross Tonnage for Engine-room.	No. of Iron Screw Vessels.	Per-centage of Deduction from Gross Tonnage for Engine-room.	No. of Wooden Paddle Vessels.	Per-centage of Deduction from Gross Tonnage for Engine-room.
1	13	1	5	1	12
2	15	1	7	1	15
1	17	1	9	1	17
2	18	1	10	2	19
1	20	1	11	2	20
5	22	2	15	1	21
1	23	4	16	1	22
4	24	3	17	5	23
4	25	10	19	5	25
5	26	6	20	6	26
5	27	5	21	4	27
7	28	14	22	8	28
6	29	8	23	8	29
23	30	17	24	24	30
8	31	13	25	13	31
12	32	11	26	18	32
9	33	18	27	26	33
13	34	12	28	23	34
15	35	19	29	23	35
15	36	12	30	17	36
9	37	7	31	28	37
8	38	13	32	20	38
12	39	12	33	18	39
13	40	3	34	37	40
12	41	4	35	21	41
7	42	5	36	14	42
5	43	3	37	23	43
10	44	6	38	20	44
8	45	7	39	10	45
6	46	6	40	18	46
5	47	9	41	10	47
4	48	4	42	7	48
7	49	1	43	3	49
5	50	1	45	18	50
1	51	6	46	8	51
1	53	2	47	10	52
1	54	2	48	5	53
1	55	2	49	12	54
2	56	4	50	6	55
2	57	1	51	18	56
1	58	2	52	11	57
2	59	1	55	12	58
1	60	1	57	15	59
3	63	1	60	18	60
1	65	1	63	13	61
1	68	1	74	15	62
1	69			20	63
1	72			17	64
1	74			24	65
1	75			26	66
1	81			19	67
1	82			17	68
1	92			40	69
Total 274		264		742	

No. of Wooden Paddle Vessels (*continued*).	Per-centage of Deduction from Gross Tonnage for Engine-room.
742	
31	70
18	71
19	72
16	73
14	74
7	75
10	76
2	77
2	78
2	79
1	80
1	81
2	82
1	85
1	88
2	89
871	
60*	
931	

No. of Wooden Screw Vessels.	Per-centage of Deduction from Gross Tonnage for Engine-room.
1	22
1	24
1	25
1	26
2	29
1	30
1	35
1	38
1	54
10	

SUMMARY OF TABLE.

Iron Paddle Vessels ...	274
Iron Screw Vessels	264
Wooden Paddle Vessels.	931
Wooden Screw Vessels..	10
Wood and Iron Paddle (with 26 per cent. deduction from gross tonnage for engine-room)	1
	1480

* The full data are not given to enable the calculations to be made, in the case of these 60 wooden paddle vessels.

General Summary.

Imports.					
Date.	No. of Vessels.	Register Tonnage.	Tons Weight of Cargo carried.	Difference of Cargo, with reference to Tonnage.	Per Centage of Difference.
1852	38,051	7,887,447	6,169,599	−1,717,848	−21
1853	42,876	8,943,106	7,525,063	−1,418,043	−15
1854	41,591	9,161,366	7,290,996	−1,870,370	−20
1855	40,980	8,951,239	6,254,259	−2,696,980	−30

Exports.					
Date.	No. of Vessels.	Register Tonnage.	Tons Weight of Cargo carried.	Difference of Cargo, with reference to Tonnage.	Per Centage of Difference.
1852	39,361	8,242,702	6,418,245	−1,824,457	−22
1853	44,779	9,447,104	7,316,457	−2,130,647	−22
1854	43,494	9,507,721	7,639,473	−1,868,248	−19
1855	42,597	9,538,231	8,370,363	−1,167,868	−12

June, 1858. HENRY WRIGHT.

Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results. By the Rev. H. Lloyd, *D.D., M.R.I.A.*

The Irish portion of the magnetic survey of the British Islands was commenced in the beginning of August last, and is now nearly terminated, nothing remaining for its completion but the determination of some of the instrumental constants. The observations in the northern half of Ireland were made by Profs. Galbraith and Haughton, and those of the southern half by Dr. Lloyd and G. Johnstone Stoney, Esq. The instruments employed were similar in the two divisions of the island, and consisted of a theodolite magnetometer, and of a dip circle furnished with an apparatus for the determination of the earth's magnetic force in absolute measure. The comparability of these instruments was established by observations taken at Dublin at the commencement of the survey. The elimination of the magnetic changes will be effected by means of simultaneous observations made at the magnetical observatory of Dublin. The theodolite magnetometer for the measurement of the magnetic declination differs somewhat from instruments of a similar nature hitherto in use,—the difference consisting in observing the sun (or other celestial object) *by reflexion*, and transferring the transit adjustments to the axis of the mirror employed for that purpose. By this arrangement, the observing telescope is always horizontal, and in readiness for the magnetic part of the observation. The instrument is furnished also with the means of determining the horizontal component of the magnetic force in absolute measure; but this was not employed, the determination of the total intensity by means of the dip circle leaving nothing to be desired. The apparatus required for this latter determination consists of two additional needles, one of which is loaded with a small weight, placed at a fixed distance from the centre on the southern arm. The observation consists of two parts, in one of which the *product* of the earth's magnetic force into the magnetic moment of the magnet is found by observing the position of equilibrium of the loaded needle, when placed on the agate planes; while, in the other, the *ratio* of the same quantities is found by employing the same needle to deflect another substituted in its place. The apparent obstacle to the success of this method lies in the smallness of the angle of deflection produced by a dipping-needle, when employed as a deflector at the usual distances; the error of the deduced force being inversely as the sine of the angle of deflection. The equation of equilibrium of the deflected needle involves a quantity, which may be expanded into a series of the inverse odd powers of the distance (beginning with the inverse third), the coefficients of which are functions of certain integrals depending on the distribution of magnetism in the two needles. The law of distribution being unknown, these coefficients can only be determined by repeating the observation at several known distances, and eliminating among the resulting equations. Now, at the distances usually employed in observations of deflection, the angle of deflection produced by a dipping-needle would be too small for accuracy; and if the distance be diminished, the number of terms of sensible value will be increased, and there will arise increased difficulty and uncertainty in the elimination. This difficulty is avoided by availing ourselves of a circumstance which appears to have been generally overlooked. It is not necessary that the usual deflection distance should be one of the series employed in deducing the coefficients of the inverse powers of the distance in the value of the constant; it is not even requisite that the relative positions of the two magnets should be similar in the two cases: for if the value of the corresponding function be found, for *any* other position, and at *any* other distance, that of the required function will be known by a comparison of the deflections produced. Accordingly, the principle of the present method (so far as the deflection process is concerned) consists in observing the angle of deflection in the regular series of observations, at a very short distance, the deflecting needle being attached to the moveable arm of the divided circle which carries the verniers, so as to be always rendered perpendicular to the deflected needle in the course of the observation. In the determination of the constant the whole apparatus is to be turned in azimuth, until the deflected needle is vertical. The deflecting magnet is then to be removed from its usual position above described, and placed horizontally on a support outside the box on a level with the agate planes, and the equilibrium produced by turning the apparatus in azimuth as before. This observation having been repeated at several known distances, we have all the data for the determination of the unknown constant. By these means the uncertainty of the result, arising from the smallness of the angle of deflection, is removed from the regular series of observations, and thrown upon the determination of the constant, which may be made at leisure, and repeated as often as is requisite for accuracy. Even when the constant is undetermined, the instrument may be used to observe the total force *relatively*,—the method having this advantage over other relative methods hitherto used, that the results are completely *independent of the changes of the magnetic moments of the needles* in the intervals of observation. Dr. Lloyd concluded by stating some of the results of the survey, so far as they have been calculated. But as these calculations are still incomplete, the results can only be regarded for the present as provisional.

Report of Dublin Dredging Committee, appointed 1857–58. *By* Professor J. R. Kinahan, *M.D., M.R.I.A.*

During the past year, the following districts, all in the immediate vicinity of Dublin, have been examined:—Killiney Bay, Bray Head, Kish Bank, South Strand, Dalkey Sound, Howth, Malahide, Lough Shinny, Bettystown, and considerable advance made towards the completion of the Report. The following numbers of species have been catalogued:—

Fishes, 60; Mollusca, including Polyzoa, 262; Crustacea, 105; Arachnida, 5; Echinodermata, 29; Hydrozoa, 60; Actinozoa, 17; Sponges, 10; and many Annelides not yet identified. Various untoward events prevented the Committee from carrying out fully the dredging arrangements which they had made at the commencement of the year. For the better perfecting of the Report, they have determined to allocate to the several Members of the Committee certain classes of animals as the special object of study, and have divided these as follows:—Professor Kinahan, M.D., Articulata and Sponges; Dr. Carte, Vertebrata; Dr. Wright, Mollusca; and Professor J. R. Greene, Echinodermata, Cœlenterata, &c. They propose also to include in their final report, as complete a list of the fishes of Dublin Bay as practicable, for which, as well as the further prosecution of their dredging researches, they would ask for a grant not exceeding £15 for the year 1858–59, the Committee consisting, as last year, of Professor Kinahan, Dr. Carte, Dr. Wright, and Professor Greene.

Report on Crustacea of Dublin District. By John Robert Kinahan, *M.D., M.R.I.A., Professor of Zoology in the Department of Science and Art.*—Part I. Decapoda Podophthalmata.

The marine districts comprised in this Report consist of a series of open bays, into most of which a river-mouth enters; and of one or two extensive sand-banks which lie off the east coast of Ireland.

The chief stations are—Dublin Bay and the estuaries of the rivers Dodder, Anna Liffey, and Tolka; a long lighthouse pier separates this into subdistricts—the North and South Bulls. The South Bull is almost exclusively fine sand, containing great numbers of broken shells, being made up from the washings of a cliff of marine drift; an extensive strand, left dry here at low water, is dotted over with sand-pools, in which *Carcinus Mænas, Mysis vulgaris, Mysis Chamæleon, Palæmon squilla, P. varians, Crangon vulgaris, Gammarus locusta, Gammarus palmatus* and other species are found. A tidal stream called the Cockle lake, divides the bed of drift already spoken of from the strand proper; this at high tides is in many places from 2 to 3 fathoms deep, but is singularly destitute of crustacea; the bottom is a quicksand.

Passing along from this station towards Kingstown Harbour, we meet several patches of Zostera, in which *Port. holsatus* is found in some numbers; having passed Kingstown, the bay becomes rocky, one or two zostera-clad banks, here called Mullet Grass, being interspersed among the rocks; one of these, near Sandycove, furnished me at low water with the following species:—*Hippolyte varians, H. Cranchii, Pandalus leptorhynchus* (new species), *Mysis vulgaris* and *chamæleon, Crangon vulgaris, Crangon fasciatus, Apseudes talpa, Atelecyclus heterodon.*

Dalkey Sound, a narrow channel, separating Dalkey Island from the main land and from 8 to 10 fathoms deep, bounds the Dublin station. In the Sound, the following species occur:—*Portunus depurator*, *puber*, *holsatus* and *pusillus*, *Inachus Dorynchus* and *Dorsettensis*, *Hyas coarctatus*, *Eurynome aspera*, *Pirimela denticulata*, *Pinnotheres pisum*, *Ebalia Pennantii* and *Cranchii*, *Bernhardus Streblonyx*, *Thompsonii*, *Cuanensis*, *Ulidianus* and *Hyndmanni*, *Galathea Andrewsii*, *strigosa* and *squamifera*, *Palinurus vulgaris*, *Hippolyte varians*, *Thompsonii* and *pusiola*, *Pandalus annulicornis*, and many of the commoner species.

Killiney Bay, which succeeds this, and is bounded by Bray, is partly sand and part shingle and rocks; it calls for no detailed description. At Bray the Bray river enters and forms a mud bank in about 10 fathoms to the south of Bray Head; here, in the lobster pots, *Palæmon serratus* has been said to have been taken. Distant about 7 miles from Bray Head is a bed called the Scallop bed, part of the Kish bank, the water varying from 6 to over 25 fathoms. Here many rare and one previously undescribed species has occurred, such as *Crangon sculptus*, *Crangon Allmanni*, *Galathea Andrewsii*, all the *Bernhardi*, except *Prideauxii*, the two *Ebalias* already mentioned, *Acanthonotus testudo*, *Ampelisca typicus*, *Nephrops Norvegicus*.

The North Bull, owing to the influx of the three rivers already named, is chiefly mud passing into rock at Howth: this district has never been carefully explored, but the following species are often thrown upon the white sand, a bank similar to that already noted as the South Bull: *Corystes Cassivelaunus*, *Portumnus variegatus*, *Pilumnus hirtellus*.

Balscaddan Bay, Howth, is rocky; here *Amphitoe littorina* is common, *Hippolyte varians*, *Hippolyte Cranchii*, *Mysis vulgaris* and *chamæleon*, *Porcellana platycheles*.

Portmarnock Bay, which next succeeds, is chiefly sandy, slob banks occurring in parts. At Malahide a great muddy estuary, due to the influx of the Swords river, is found. This mud slob is separated from that at Rush and Lusk by the Burrow of Portrane, which is sandy like the two Bulls; to the north of this the coast becomes rocky till we get to Skerries, where three islands cause the formation of a bank, from which in 10 fathoms the late Robert Ball, LL.D., procured *Crangon trispinosus*, and *Diastylis Rathkii*.

From Skerries to the mouth of the Boyne the beaches are all sandy, and call for no special remark.

Two outlying stations, viz. Ireland's Isle, or Eye, near Howth and Lambay, which lie abreast of Portrane, have afforded many rarities; but never having personally examined them, I must defer particular notice of them till some future period.

The fluviatile districts afford us *Astacus fluviatilis*, *Gammarus fluviatilis*, besides Entomostraca in abundance. At the mouths of rivers many of the marine species ascend even into the fresh water; these are marked in the accompanying Tables as subfluviatile; they are *Crangon vulgaris*, *Mysis chamæleon*? and *vulgaris*, *Gammarus fluviatilis*, *Spheroma serratum*, *Orchestia lævis*, *Orchestia littorea*, *Corophium longicorne*, *Carcinus Mænas*.

The terrestrial species are at present recorded in greater numbers than in any other district, probably having been more sought after, all the genera, save *Platyarthrus*, being represented here. The chief species wanting in the Dublin lists are those which frequent deep water, and which will probably be yet found when the deeper parts of the Bay are better searched. Mud burrowers are also absent, which will most certainly yet be found. It is intended to embody all remarks bearing on the peculiarities of the distribution of species in the last part of this report; at present I shall content myself with a summary of the species belonging to the Decapoda found here, contrasting this with the numbers found in Great Britain generally, and also with those found in Ireland.

The exact habitat of several species recorded here is as yet a desideratum, although some of these are by no means rare as drift species; these are *Portumnus variegatus*, *Corystes Cassivelaunus*, extremely common; *Gonoplax angulatus*, drifted in at Portmarnock (supposed to inhabit mud banks near Knocknagin; for this note I am indebted to Charles Farran, M.D.); *Atelecyclus heterodon* (full-grown specimens), *Portunus arcuatus*, *Portunus corrugatus*, *Galathea nexa*, *Bernhardus Prideauxii*, *Palæmon serratus*, *Palinurus vulgaris*.

The following species have as yet been noted only on the Dublin coast:—*Crangon Allmanni* (also Belfast, August 1858), *Pandalus leptorhynchus*, *Iphimedia Eblanæ*.

The following has not occurred elsewhere in Ireland:—*Crangon trispinosus*; and many species, as *Crangon sculptus*, *C. fasciatus*, *Pirimela denticulata*, are of extreme rarity elsewhere.

In Dublin Bay, as will be seen by reference to Table B, Appendix, have been recorded fifty-nine species of Decapoda out of the ninety-one positively recorded in Ireland. These represent thirty genera,—the genera wanting here being *Maia*, *Pisa*, *Achæus* (?), *Polybius*, *Thia*, *Nika* (?), *Alpheus*, *Athanas*—all genera of the south and west; *Munida*, *Gebia*, *Calocaris*, *Callianassa*, genera of deep sea or mud-burrowers, and *Cynthilia*, *Macromysis*, *Vaunthompsonia*, *Iphinoe*, and *Cyrianassa*, genera as yet but little understood and easily overlooked. *Pasiphaë* is the only genus which has not been met elsewhere in Ireland; its occurrence in Dublin is doubtful (vide Appendix, Table A).

Of the thirty-two Irish species not recorded in Dublin and not belonging to the genera here noticed, *Xantho rivulosa* and *tuberculata*, *Portunus carcinoides* and *marmoreus*, *Pinnotheres veterum*, *Hippolyte Mitchelli*, *Palæmon Leachii*, *Mysis Griffithsii* (?), are probably western and southern. *Inachus leptochirus*, *Crangon bispinosus*, *Bernhardus Forbesii*, inhabitants of deep water, and *Crangon spinosus*, a northern species; *Bernhardus lævis* and *Achæus Cranchii* have been reported to me, but I hesitate to insert them at present.

As compared with the numbers given as British, it must be borne in mind that among the latter are included many whose specific value is doubtful; at the same time we could scarcely expect that all the *northern* or *southern* species which occur around the coast of Great Britain, should ever be found here. Of most of the species recorded here, I have procured specimens in ova, from many of which I have succeeded in hatching the zoes; these, should time permit, I would propose to notice in the concluding portion of my report, when I come to speak of the development of the group generally.

Lists of the genera, families, and species are appended.

APPENDIX.

TABLE A.—Tabular view of Genera of British Crustacea Podophthalmia, showing distribution of genera in Dublin as contrasted with the whole of Ireland and with Great Britain and the Sarnian provinces.

Families and Genera.	Dublin.	Irish.	Not found in Great Britain.	British and Sarnian.	
EUBRANCHIATA.					
Brachyura.					
Maiadæ.					
Inachus	2	3	....	3	
Maia	....	1	....	1	
Pisa	....	1	....	2	
Hyas	2	2	....	2	
Leptopodidæ.					
Achæus	....	1	....	1	
Stenorhynchus ...	1	1	....	2	
Lambridæ.					
Eurynome	1	1	....	1	
Cancridæ.					
Pirimela	1	1	....	1	
Cancer	1	1	....	1	
Xantho	*(1)	3	....	3	*Very doubtful, *X. florida*.
Eriphidæ.					
Pilumnus	1	1	....	1	
Portunidæ.					
Portunus	6	8	1*	9	**Portunus carcinoides*.
Platyonychidæ.					
Carcinus............	1	1	....	1	
Portumnus.........	1	1	....	1	
Polybius............	....	1	....	1	
Thiidæ.					
Thia	....	1	1	1*	Channel Islands.
Corystidæ.					
Atelecyclus.........	1	1	....	1	
Corystes	1	1	....	1	
Gonoplacidæ.					
Gonoplax	1	1	....	1	
Pinnotheridæ.					
Pinnotheres	1	2	....	2	
Grapsidæ.					
Planes	....	......	....	1	Not Irish.
Leucosiadæ.					
Ebalia	2	3	....	3	
Anomoura.					
Dromidæ.					
Dromia	....	......	....	1	Not Irish.
Lithodidæ.					
Lithodes............	....	......	....	1	Not Irish.
Paguridæ.					
Bernhardus	6 (1*?)	8	....	9	**B. Prideauxii* very doubtful.
Paguristes	....	......	....	1*	**Pag. Dilwynnii* not Irish.
Porcellanidæ.					
Porcellana	2	2	....	2	
Galatheidæ.					
Galathea	3	8	....	9	
Munida	....	1	....	1	

Table A (*continued*).

Families and Genera.	Dublin.	Irish.	Not found in Great Britain.	British and Sarnian.	
Macroura.					
Gebidæ.					
Gebia	....	1	....	2	
Axius	....	......	....	1	Not Irish.
Calocaris	....	1	....	1	
Callianassidæ.					
Callianassa.	....	1	....	1	
Scyllaridæ.					
Arctus	....	......	....	1	Not Irish.
Palinuridæ.					
Palinurus	1	1	....	1	
Astacidæ.					
Homarus	1	1	....	1	
Astacus	1	1	....	1	
Nephrops	1	1	....	1	
Crangonidæ.					
Crangon	5	8	2*	8	**C. Allmanni, C. Pattersonii.*
Nika	....	2	....	1	
Palæmonidæ.					
Alpheus	....	1	1*	2	**A. affinis.* Guernsey.
Autonomea	....	......	....	1	Not Irish.
Athanas	....	1	....	1	
Hippolyte	4	5	....	15*	*All the doubtful species are included.
Pandalus	2	2	1*	3	**P. leptorhynchus.*
Palæmon	3	4	....	4	
Pasiphæidæ.					
Pasiphaë	1	1	....	1	
Panæidæ.					
Penæus	....	......	....	1	Not Irish.
ANOMOBRANCHIATA.					Not found in Ireland.
Stomapoda.					
Squillida.					
Squilla	....	......	....	2	
Schizopoda.					
Euphausidæ.					
Thysanopoda	....	......	....	1	Not Irish.
Mysidæ.					
Cynthilia	....	1	....	1	
Mysis	3 (1?)	4	....	7	
Macromysis	....	1	....	2	
Diastylidæ.					
Diastylis	1	1	....	1	
Cuma	....	......	....	2	Not Irish.
Vaunthompsonia	....	1	1*	2	**V. cristata.*
Eudora	....	......	....	1	Not Irish.
Iphinoë	....	1	....	1	
Bodotria	....	......	....	1	Not Irish.
Cyrianassa	....	1	1*	2	**C. longicornis.*

The first column gives the number of species found in Dublin; the second the number certainly known as Irish; the third contains those which, while found either in Ireland or the Channel Islands or both, are as yet unknown in Great Britain; whilst the column marked British is intended to show the number of species found on the shores, &c. of Great Britain, Ireland, and the Channel Islands. The families and genera not yet proved to be represented in Ireland are *italicized*. The following summary shows the contrast between these several districts as regards the number of species and genera.

TABLE B.—Summary of number of species and genera.

Districts.	Eubranchiata.			Anomobranchiata.		
	Macroura.	Anomoura.	Brachyura.	Stomapoda.	Schizopoda.	Aploopoda.
Dublin	19	11 (1?)	25 (1?)	......	3 (1?)	1
Ireland	30	15	36	......	6	4
Not found in Great Britain	4	......	2	......	......	2
British	47	20	40	2	11	9

Totals:—
Species, Irish ...... 91. Dublin ...... 59. British ...... 129.
Genera, Irish ...... 47. Dublin ...... 30. British ...... 58.

The following is a detailed list of the species found hitherto in Dublin;—

TABLE C.—Species of Crustacea Podophthalmia inhabiting Dublin Districts.

* Common. ** Very common. † Rare. ‡ Very rare. L. local.

Name of Species.	Ratio of occurrence.	Zone of distribution.	Remarks.
Inachus Dorynchus	*	Coralline.	
—— Dorsettensis	†	Coralline.	
Hyas araneus	**	Littoral—Laminarian.	
—— coarctatus	**	Laminarian—Coralline.	
Stenorhynchus phalangium	**	Littoral—Coralline.	
Eurynome aspera	*	Coralline.	
Pirimela denticulata	‡	Do.	One specimen only.
Cancer pagurus	**	Littoral—Laminarian.	
Pilumnus hirtellus............	†	Laminarian—? littoral.	
Portunus puber	**	Littoral—Laminarian.	
—— corrugatus	‡	Littoral ?	One young specimen.
—— arcuatus	‡	Do. ?	Do.
—— depurator	*	Laminarian—Coralline.	
—— pusillus	**	Laminarian—Coralline.	
—— holsatus	*	Do. Do.	Rather local.
Carcinus mænas	**	Littoral—Laminarian.	
Portumnus variegatus	*	....	Never dredged.
Atelecyclus heterodon	†	Littoral	Only young met.
Corystes Cassivelaunus......	*	Littoral	Never dredged.
Gonoplax angulatus	†L.	Littoral	Never dredged.
Pinnotheres pisum............	**	‡Laminarian—Coralline.	
Ebalia Pennantii	†	Coralline.	
—— Cranchii	‡	Do.	Obtained by R. Ball, LL.D.
Bernhardus Streblonyx ...	**	Littoral—Coralline.	
—— Prideauxii	‡	....	A single dead specimen.
—— Thompsonii	*	Coralline.	
—— Cuanensis	**	†Laminarian—Coralline.	

Table C (*continued*).

Name of Species.	Ratio of occurrence.	Zone of distribution.	Remarks.
Bernhardus Ulidianus	**	†Laminarian—Coralline.	
—— Hyndmanni	**	Do. Do.	
Porcellana platycheles	*I..	Littoral—Laminarian ...	Extremely local.
—— longicornis	**	Littoral—Coralline.	
Galathea squamifera	†	Laminarian	Never dredged.
—— Andrewsii	**	Coralline, &c.	
—— strigosa	†	Laminarian	Never dredged.
Palinurus vulgaris	‡	Laminarian and Coralline.	
Astacus fluviatilis	*	Fluviatile.	
Homarus vulgaris	**	Laminarian	Never dredged.
Nephrops Norvegicus	**	Coralline, &c.	
Crangon vulgaris	**	Littoral—Laminarian	Also subfluviatile.
—— Allmanni	*	Coralline.	
—— sculptus	*	Do.	
—— fasciatus	†	Laminarian.	
—— trispinosus	†	Coralline	Robert Ball, LL.D.
Hippolyte varians	**	†Littoral—Laminarian — ‡Coralline.	
—— Thompsoni	*	Laminarian—Coralline.	
—— Cranchii	*	Littoral—Laminarian.	
—— pusiola	**	Laminarian—Coralline.	
Pandulus annulicornis	**	†Laminarian—Coralline.	
—— leptorhynchus	‡	Laminarian	One specimen.
Palæmon squilla	**	Littoral—Laminarian ...	Never dredged.
—— serratus	‡	Coralline	Do. do.
—— varians	*	Littoral—Laminarian......	Do. do.
Mysis Chamæleon	**	Littoral—Laminarian	Also subfluviatile.
—— vulgaris..................	**	Do. Do.	Do. do.
—— —— ?	...	Laminarian	Sandycove.
Diastylis Rathkii	†	Coralline	Robert Ball, LL.D.

Xantho florida is stated also to have occurred, but needs confirmation; it may possibly occur in Lambay Island.

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. By ANDREW HENDERSON, *A.I.C.E., M.S.A., F.R.G.S.*

[A Communication ordered to be printed entire among the Reports.]

1. *Comprehensive Objects aimed at.*—The object of this paper is to offer some suggestions for the improvement and extension of steam navigation on the Ganges, Burhampootra, and Irrawaddy, in the east, and on the Indus and the Punjaub rivers on the west, now forming the river boundaries of England's empire in India; the coasts and harbours affording a desirable field for maritime enterprise, and the employment of British shipping. The valleys, deltas, and upper affluents of those rivers extend many thousand miles through some of the most populous and fertile regions in the world, the whole route from east to west traversing the most ancient sites of civilization and channels of trade, there being a probability that the navigation of the Indus

will be brought into connexion with the Ganges by means of a canal uniting their upper branches so as eventually to enable vessels of suitable form and dimensions to pass uninterruptedly from Kurratche on the west coast, through the whole riverine system of British India.

2. *Proposal for the attainment.*—Of late years many plans and proposals have been brought forward for improving and extending the means of internal communication in India, and of laying open to European commerce and civilization the productive resources and capabilities of the country.

3. These projects may be divided into two classes,—those which consist in improving the means of land transport, and those which refer to water transport.

Of the first class there are three kinds—roads, tram-roads, and railroads; of the second there are also three kinds:—river navigation in the main channels, canal navigation in connexion with irrigation, and lastly, that which forms the subject of the present paper—the navigation of the shallow creeks, upper branches, and minor affluents of the great Indian rivers and deltas.

4. Of the first class, all require not only the construction of vehicles, but of the tracks which the vehicles are to traverse, and are consequently expensive, and require a considerable period of time before they can be brought into practical operation.

Of the second class, with the exception of canals which are supposed to be constructed with other views than that of being only navigable channels, the others merely require the construction of the vehicles, and are consequently the cheapest, simplest, and at the same time the most readily available.

5. To make the importance of the utilisation of the existing means of communication by shallow-water navigation more readily understood, it may not be out of place to make a few general remarks upon each of the plans above enumerated.

6. *Present Roads in India.*—First, as to roads—such as deserve the name in India, have hitherto been those which were necessitated by considerations affecting the military tenure of the country, or were confined to such trunk-lines of communication as afforded the greatest facilities for military operations, conjointly with the most pressing requirements of the commercial interests of the community. In all countries (where water transport is not available) the number and excellence of the roads may be taken as a fair index of the condition of the population, and the surest test of their comparative progress in civilization. Judged by this standard, it is not, perhaps, overstating the present condition of the greater portion of our Indian empire to say, that it is hardly above the level of Britain during the occupation of the Romans.

7. There were splendid military roads leading from one great military station to another; if these stations coincided with commercial positions of importance, that was an advantage of secondary importance.

8. That such should in a great measure have been, until recently, the condition of British India, may be matter of regret, but it would scarcely be fair to lay the blame exclusively upon the government of the East India Company. Since the relinquishment of their charter as traders, their first duty was to govern the country, to maintain order, peace, and tranquillity. Accordingly, whatever was done in furtherance of these ends was done, and done well; but it was obviously impossible, considering the extent of territory under their sway, to do anything beyond constructing such trunk-lines of communication as were required for military and strategic purposes.

9. In these modern days of large enterprises, however, there seems to be a fatal tendency "to run before we learn to walk," to overlook and despise

the necessity of turning to the most natural and preliminary means of intercourse, which ought to precede and pave the way for more improved and costly means of traffic. Because we cannot do all, we are disposed to do nothing; because we cannot have railways, we neglect to make the roads by which the railways might be fed and supported; and, lastly, because in such a poor country we cannot afford to construct public roads, we refuse, unless in a very imperfect and limited way, to turn to account the existing facilities for water transport afforded by the numerous upper branches and minor affluents of the great Indian rivers which traverse the country in every direction.

10. *Available Shallow-water Navigation.*—Of all conceivable means of transport from one place to another, that by water (where a smooth and level highway is provided by nature) is at once the most universal, simple, and least expensive. It is very certain that the coracle and the canoe were in use long before the existence of wheeled carriages and roads adapted to them, for the very obvious reason, that carriages even of the rudest description require a road to be prepared for them. The ground requires, to a certain extent, to be levelled and freed from obstructions along the whole route which the vehicle has to traverse; whereas, in water transport, the route is made and levelled to hand; all that was required was a hollow tree, or a raft of loose branches tied together. There was, moreover, this additional advantage, that such a mode of conveyance required less labour for traction, and at the same time admitted of the application of other than human or animal labour, by turning to account the propulsive power of the winds, tides, and other currents.

11. Of all the different modes by which it is proposed to increase the means of internal communication in India,—roads, tram-roads, and railroads, river navigation, canal navigation, and the utilisation of the shallow water channels—there is not one but what is under certain local and commercial conditions, good and expedient; but it ought to be borne in mind that they have each and all a certain natural and inevitable relation to each other; that is, the most improved and expensive means of communication (as regards the first outlay) must be preceded and aided by the next lowest, or rather the next more simple and less expensive mode.

12. Pathways are feeders to turnpikes, and these to railroads; and as a multiplicity of small streams unite to form even a small river, so do these latter in turn unite to form the main current of the principal rivers.

13. As before stated, the most universal, the simplest, and least expensive means of transport is that afforded by the natural water channels already existing in the country, and which constitute the general basis from which all the other and more improved means have been derived and rendered practicable. But with our usual tendency to expensive and ponderous modes of procedure, the system of most of the water transport organized by Englishmen in India has been encumbered by the extended scale upon which it has hitherto been attempted. Nothing short of steamers of the same construction and dimensions as those in use in England and America have been thought eligible for the requirements of river navigation in India.

14. Now, viewing the main channels of the principal rivers as trunk-lines of traffic, there cannot be a doubt that vessels of considerable dimensions are desirable for the conveyance of the large and regular amount of traffic which is to be anticipated on a trunk-line of communication; but this advantage of using vessels of large dimensions is limited by the disadvantage of the greater draft of water which they require, owing to the increased weight of the vessels themselves. This increase in the draught of water precludes

vessels of large dimensions from entering the upper branches and minor tributaries of the great Indian rivers.

15. Taking into account the provisions already made, or in process of construction for opening up the interior of India, by trunk-lines of railway, by roads, canals, and steam navigation on the main channels of the great rivers, and also taking into account the present and probable future condition of India for many years to come, it would appear that the most urgent and imperative requirements of India are not so much for additional trunk-lines of traffic, as for feeders to supply them—not so much for main arteries of commerce as for the capillaries by which they are to be kept alive. Railways in India or elsewhere would be comparatively useless if it were not for the means by which merchandise is conveyed to their termini.

16. However comprehensive the scheme by which the railway system of India has been arranged, no system which does not take into account the minor tributaries or existing means of communication with their termini can be considered complete.

17. *The Improvement of Native Boats proposed.*—The entire traffic on the upper branches and minor affluents of the great rivers is at present conducted by means of native boats of a peculiar description, which have been in use from the earliest periods; and since the construction of roads by the natives themselves has ever been most unwillingly undertaken, there can be no hope of their ever improving much in this respect.

18. There is therefore every certainty that for many years to come these native boats must be the means of conveying the great bulk of Indian produce either to the termini of the railways, or to those stations on the main channels of the great rivers which can be reached by the large steamers now employed.

19. From this point of view, then, it will be seen, that on the improvement of the native river craft depends a very considerable portion of whatever success may attend the opening up of the country by trunk-lines, either of roads, canals, river navigation, or railways.

20. *Review of Native Boats and record of the earliest Steamers built in Bengal.*—With the view of calling public attention to the important functions fulfilled by these boats, I have prepared the accompanying brief description of the principal types of vessels now in use.

21. Quoting from an account of steam navigation in British India, compiled by G. A. Prinsep, Esq., and published by the Government at Calcutta in 1830, Appendix, A 4, containing etchings illustrating twenty-eight different kinds of native boats used on the Bengal rivers, from the ponderous *Budgerow* or accommodation boat and fast-pulling *Bhauleah* used by the English, to the burthensome *Patela* and *Chuprah Oolak* of forty tons,—also to the Pansuai fast-pulling fishing dinghee and *Mor Punkhee* or native pleasure-boat, all being of the Nautilus type of form, use the balanced rudder, steer-oar or skull at the stern; the latter using an oar as a bow-rudder.

22. The notable features of these vessels are, that they are generally built upon rounded lines, the bottom resembling the immersed portion of a Nautilus shell. This general contour, together with the absence of dead wood and gripe, appear to be dependent upon the character of the rudder employed, which is generally a large triangular board, with a post attached to the centre, so that the fore-part of the blade falls under what would be styled the dead wood of a river barge. The whole arrangement is intended to give the boat great facility for quick turning, to avoid sand-banks, &c. The dimensions appear to be from 20 to 80 feet in length, and from 7 to 26 feet in breadth, the draft of water varying from 1 to 5 feet, and the burden from 4 to 40 tons.

23. With a view of exhibiting the relative forms and fittings of the boats used by the natives of Bengal under different local conditions, there are given three engravings*, representing—*Figure* 1st, the Ferruckabad *katoora*, of 600 maunds burden, or 17 tons, used in the upper branches of the Ganges. *Figure* 2nd, the Decca *Pulwar*, used on the eastern branches and upper

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* BENGAL RIVER BOATS. DIFFERENT TYPES USED BY THE NATIVES.

The Katoora Type being followed in building the 'Naga' tow-boat, 1840. The type of the Ducca and Tumlook boats combined in the model of the 'Assam' steam-tug, built in Calcutta, 1841; and a combination of all three with some points of the Chinese tea-boat, together with experience since derived, forming the basis of the model and fittings of proposed *nautilus* flotilla for general purposes.

Katoora Type.

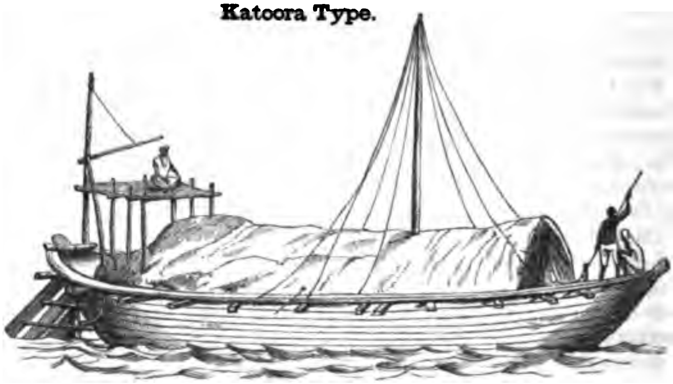


Fig 1. is the 'Ferruckabad Katoora,' of 800 maunds, or 27 tons burden, as used on the upper branches of the Ganges; they are generally tracked up the stream. It will be observed that there is a sort of skeleton guard-board extending from the gunwale: on this the crew step when propelling the boat by poles. The rudder is a large triangular blade, with a centre pole on which it is hung, with the fore-part under the stern, in place of the dead wood.

Nautilus Type.

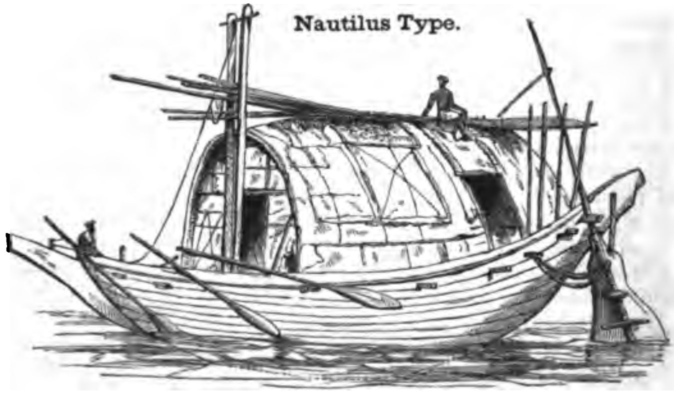


Fig. 2 is the 'Dacca Pulwar,' of 500 maunds, or 17 tons burden, used on the eastern branches and upper channels of the Deltas of the Ganges and Burhampootra. In this the 'Nautilus' contour of the bottom is well exemplified. The rudder in this case is suspended on one side of the stern, and is held in its place by lashings seen in the figure. These are well-built boats of hard wood, and use square sails.

channels of the Deltas of the Ganges and Burhampootra. *Figure* 3rd, the *Tumlook* or *Salt* boat, of 800 maunds, or 27 tons burden, plying on the Delta of the Ganges below Calcutta.

24. The publication contains 104 pages, in six chapters, on private speculation, the government sea and river steamers, detailed accounts of experiments and opinions of the late General W. N. Forbes and other officers, with plans of the following steamers:—

25. The King of Oude's steamer, built at Lucknow, the engines brought out by Mr. Henry Jessop, in 1819. The 'Diana,' built at Calcutta in 1823, and employed in the Burmese war in 1824. The 'Enterprise,' the first vessel that steamed out to India in 1825. The 'Irrawaddy' and 'Ganges,' government sea steamers, built by Mr. Seppings, at Calcutta, in 1827. There is also a plan of the Forbes steam-tug, launched in January 1829, at Calcutta, of the construction of which I had the superintendence, and in March 1830 conducted her to China, towing a vessel of 380 tons, against the monsoon, as stated in the 18th page.

26. For river navigation in the Assam valley, the government launched the 'Burhampootra' and 'Hooghly' early in 1827; the former 102 feet long by 18 broad, built by Mr. Kyd, with the round bilge design by Maudsley and Co.; the 'Hooghly' being built by Mr. I. M. Seppings, with flat floor, square bilge, and upright sides. The third and fourth chapters give details of various trials of these two, and opinions that the 'Hooghly' steered so badly, that the Marine Board considered a "rudder in the bow seemed the best remedy."

27. I have entered into this detail as the papers now before me will afford much valuable information as to the actual performances of the vessels first established by government on the Indian rivers; the peculiar character of that navigation and the difficulties to be contended with are nowhere to be found so well illustrated as in this record of practical trials, and the opinions of various sea officers, engineers, professional builders, and naval architects.

28. The fourth chapter contains information peculiarly applicable to the present pressing demand for water transport by the Great Trunk Railways, now in course of construction up the valleys of the Ganges and Indus, by the East Indian and Scinde Railway Companies. The recent crisis of a mutinous army in the valley of the Ganges (now happily past), has left the

Tumlook, or Flat Type.

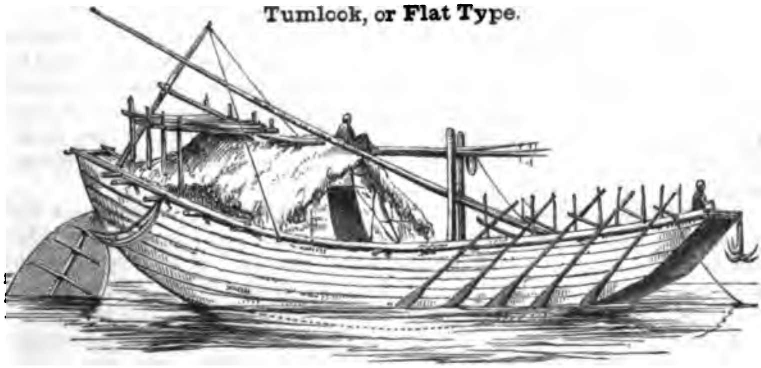


Fig. 3 is a 'Tumlook,' or 'Salt Boat,' of 800 maunds, or 27 tons burden, plying on the Delta of the Ganges below Calcutta. These have their rudders hung through a recess in the stern, and may, in common with those already described, be tilted up out of the water by means of depressing the upper end of the pole to which they are hung.

roads so unsafe for goods as to force the usual native land traffic to seek security by the private river steamers; the two established companies realizing fabulous freights of £20 to £30 per ton, and even sea-tugs towing native boats up the rivers. The exigencies of the government for military transport service, have necessitated the employing of most of the private steamers in conveying troops and stores, from the utter inadequacy of the few government vessels to meet one-third the requirements of the public service.

29. I beg to submit a brief historical analysis and tabular statement of the particulars of the various enterprises by which the steam navigation of the Ganges has been hitherto attempted.

30. In 1834 the Indian government established the first system of steam-tug and tow-boats on the Ganges. Both vessels were of similar form, dimensions, and tonnage—120 feet in length by 22 feet in breadth, and 275 tons.

31. The mode of towing may be understood by a reference to the sketch of deck plans exhibited, in which it will be seen that the two vessels were placed some distance apart.

32. The engines were from 50 to 90 horse-power, and the speed averaging from $6\frac{1}{4}$ to $7\frac{1}{2}$ miles an hour, or 50 miles a day on the upward passage, and 80 miles a day down stream in the dry season. During the rains, the rates were 40 miles and 100 miles up and down the stream respectively. Their draft of water was from 3 to 4 feet, the capability for dead weight cargo 60 to 100 tons. They were very flat-bottomed, having upright stem- and stern-posts, and large barge rudders often injured by collision.

33. *System of Tug- and Tow-Boats established on the Burhampootra, by the Assam Company.*—In 1841 the Assam Company established on the Burhampootra a system of powerful tug steamers, carrying passengers and towing smaller cargo-boats, as shown in the second line of plans in the sketch, and in the three diagrams of midship sections on the right of the centre, consisting of the 'Assam' steamer, 140 feet in length by 27 feet in breadth, 443 tons, builders' measurement, and having engines of 100 horse-power—the 'Naga' tow-boat of 90 feet in length, 18 feet in breadth, and 91 tons. These I designed for the Assam Company as adaptations of the rounded lines and "Nautilus" form of the best river-boats of Bengal, the 'Katoora,' 'Dacca Pulwar,' and 'Tumlook' boat shown in the sketch.

34. The form and mode of suspending the rudder were also derived from the same sources. Of these balanced rudders, two-thirds of the blade were placed abaft the spindles, the rudders occupying the space of the dead wood, but not extending beyond the stern. A small rudder forward occupied the same position in the bow. By this arrangement, as the vessels had no keel, the two rudders fulfilled the functions of dead wood and gripe in steady steering, and gave the power of turning the vessel on the centre, when they were placed in opposite directions.

35. The peculiar advantages of these double rudders, in steering a train of tow-boats, will be best explained by a reference to shear and deck plans of the bow and stern of two vessels of the "Nautilus" type, now proposed for military transport service, 100 feet in length, 15 feet in breadth, and 109 tons, builders' measurement. The diagram of midship sections and height of deck will be seen on the left of the centre, in juxtaposition with the sections of the 'Assam' steamer, 'Naga' tow-boat, and an iron tea-boat now navigating the Burhampootra with a native crew; the dimensions are, 75 feet in length, 12 feet in breadth, 7 feet deep, and 52 tons, builders' measurement.

36. From the difficulty experienced by the Assam Company in obtaining

labour for the cultivation of tea, the crops were so limited, that, in the absence of support from the Bengal government, there was not sufficient traffic to maintain such expensive vessels on the Burhampootra. The 'Assam' and 'Naga' were consequently employed on the Ganges, making eleven voyages to Allahabad. The other private steamers established on the Ganges were, in 1836, the Calcutta Steam-Tug Association, and from 1843 to 1845, the Ganges Steam Company and the General Inland Steam Navigation Company. The latter adopted a system of long light-built steamers, carrying passengers and towing two small cargo-boats with dead wood and gripe, and provided with large barge rudders, like the government vessels, which resulted in the loss of the first vessel, the 'Sir Herbert Maddock,' in the Hooghly. The shares of this Company, like all other steam enterprises in India unsupported by government, have fallen to one-fourth their cost, while competing for freight with public steamers. The dimensions, tonnage, and the amount of engine power employed in these vessels are here presented in a tabular form for comparison, with the amount of capital invested deducing from the displacement and weight of hull, the cost per ton of carrying capability at different drafts of water.

38. *Relative Financial Position, dependent on the capabilities for weight cargo, with Tabular Comparison of Vessels.*—This Table (p. 276, § 37) shows the relative financial position of the different enterprises, at the same cost price per ton, and in horse-power or capital expended in obtaining a capability for weight cargo, at light drafts of water which in our Indian rivers is of more importance than high speed. This was practically proved in the large and powerful 'Mirzapore' and 'Ghazeepore,' which draw too much water to be profitably employed during the dry season, to obviate which they built large light tow-boats; but experience has recently shown this was getting into another difficulty of serious magnitude. A letter from Calcutta by last mail, states,—"It is but a short time ago the Ganges Company lost a tow-boat from the same cause, being an iron vessel, very light, and over 250 feet in length; in coming up the river through the Sunderbunds, she would not answer her helm in coming round a spit of sand, and in consequence came foul of a steamer, and, in fact, cut her own throat, going down soon after."

39. It will be seen from the Table that these are the longest and largest steamers on the Ganges, and were designed on the American system of large cargo steamers; also that none of the present steamers on the Ganges carry any cargo at 2 feet draft of water. A reference to the capital columns shows a great increase of cost of capability as the draft of water decreases, the cost varying from £558 per ton at 3 feet; £88 at 4 feet in the steamers 'Patna' and 'Benares;' while, with the Nautilus flotilla of one tug and three tow-boats I have proposed, the cost of capital will be £75 per ton at 2 feet draft, £31 per ton at 3 feet, and only £19 per ton at a load draft of 4 feet, with a capability of 360 tons of dead weight cargo between the four vessels.

40. The relative capability for weight cargo of the various vessels whose particulars are given and shown on the Plan, will be best seen in the following Table (p. 276, § 41), in which the ratio of capability for weight cargo to the load displacement is stated for each, at the same draft of water, as well as their relative load displacements at the 3 feet load water-line. The Table also shows the draft at light water-line, with the displacement due to the weight of the several vessels, in tons; and also the ratio which this weight bears to the external bulk of the hull in cubic feet, as affording the best criterion of the weight of material necessary for strength.

42. *Conclusions as to form, construction, and fittings of Nautilus Tug and*

37. Tabular Financial Statement.

Names of Steamers and Tow-boats established and proposed.	Dimensions. Length.	Dimensions. Breadth.	Dimensions. Ratio.	Dimensions. Mean height of deck.	Old or B. M. tonnage.	Hull. Cost per ton.	Hull. Total cost of Hull.	Engines. Horse Power.	Engines. Cost at £50 per H. P.	Cost of Engines and Hull. Four Vessels.	Cost per ton of Carrying Capability at drafts. At 2 feet draft.	At 3 feet draft.	At 4 feet draft.	Light Draft of Water.
[Tug and Tow						£	£		£	£	£	£	£	ft. in.
Proposed Nautilus (4 vessels)	100	15	6·6	7	109	11	1,250	40	2,000	7,000	75	31	18	1 2
Iron Tea-boat	68	12	5·6	7	46	18	850	...	......	......	141	33	18	1 9
Naga Tow-boat	90	18	5·	7	91	16	1,497	...	......	......	65	25	15	1 3
Assam Steamer	140	27	5·2	7½	443	16½	7,290	100	5,000	12,290	...	296	91	2 6
Patna and Benares..............	190	28	6·8	...	733	9½	6,766	120	6,000	12,737	...	558	88	2 10
Mirzapore and Ghazeepore ...	250	38	6·66	...	1748	9½	16,134	250	12,500	28,634	...	253	88	2 5
Proposed Indus Steamer	350	46	7·6	5⅛	3741	10	37,410	200	10,000	47,410	...	...	...	...
Bengal Government Steamers.	125	20	6·25	7	275	...	......	70	......	......	...	...	...	...

41.

Tonnage. Old or Builders'.	Tonnage. Relative Tonnage.	Names of River Steamers, Tugs, and Tow-boats.	Light Water-lines. Draft of Water.	Light Water-lines. Weight of vessel in ton.	Light Water-lines. Ratio external bulk, ton wht. of hull.	Load Water-line—Draft 2 feet. Displacement—in tons.	Capability for weight cargo.	Ratio.	Load Water-line—Draft 3 feet. Displacement—in tons.	Capability for weight-cargo.	Ratio.	Relative Load Displacement.	Load Water-line—Draft 4 feet. Displacement—in tons.	Capability for weight-cargo.	Ratio.	External bulk to medium height of deck.	Relative Bulk.
tons.		[Tug and Tow	ft. in.		cub. ft.		tons.			tons.				tons.		cub. ft.	
109·0	2·3	Proposed Nautilus (4 vessels)	1 2	30	282	58·0	28·0	·48	91·6	61·6	·67	1·93	129·0	99·0	·77	8452	1·82
46·5	1·0	Iron Tea-boat	1 9	25	185	32·9	7·9	·21	50·5	25·5	·41	1·00	71·0	46·0	·65	4624	1·00
91·0	1·9	Nago Tow-boat	1 3	30	241	53·2	23·2	·44	88·6	58·6	·66	1·77	126·0	96·4	·76	7229	1·56
443·0	9·3	Assam Steamer	2 6	159	...	...	nil.	...	200·5	41·5	·27	4·12	293·5	134·5	·46	...	...
733·0	13·6	Patna and Benares Steamer...	2 10	305	...	...	nil.	...	328·0	23·0	·07	6·26	446·0	140·0	·31	...	...
1748·0	37·6	Mirzapore and Ghazeepore Steamers	2 5	420	...	...	nil.	...	533·0	113·0	·21	10·05	745·0	325·0	·45	...	...
3741·0	80·0	Proposed Indus Steamer for Railway Company	...	...	...	665·0	...	...	1049·0	...	...	...	...	...	...	76400	16·3

Tow-boats from 100 *to* 200 *feet long, in Flotillas of four vessels of small class to two of largest, to meet the present requirements of the Bengal Rivers.*—Taking all the data given, both with regard to what is required, and what has been done in meeting these requirements, I have arrived at the following conclusive opinions:—

43. 1st. It is better to attempt constructing a vessel adapted for the general purposes of inland and coast navigation, than to endeavour to supply special local requirements. 2nd. That for the present exigencies of Government and the railway companies, together with the aspect of the country in the probabilities to be anticipated, the wants of all will be most cheaply, speedily, and effectively supplied, by adopting a uniform model, and system of fittings and towing, which, with slight modifications suggested by local circumstances, may be readily adapted to each case; the following being the smallest vessels to which steam can be economically applied, and the largest conveniently navigated, by native crews without steam.

44. *Dimensions.*—To be 100 feet in length, 15 feet in breadth, and 6 feet in depth, the deck extending one-third of the breadth beyond the sides to form a guard board; the roof of the deck-houses to rise 15 feet above the keel for half the breadth and length of the vessel.

Proportions.—To range from eight breadths to five, as circumstances may require.

Form.—Where light draft is essential, the main breadth to extend for about three breadths, or half the length of the vessel, the middle of the main breadth or dead flat to be one-third of the breadth abaft the centre of the vessel's length; the bottom of bow and stern to be curved up from the dead flat to the extremities of bow and stern; the angle of rise of floor to be one degree, and the bilge to be turned within one square foot.

45. In the arrangement proposed, the cargo, boilers, and fuel are placed below, while the engine and passengers are placed above the deck. The framing of the deck-houses is made subservient to the strengthening of the vessel longitudinally, and although in connexion with the framing of the vessel, it is distinct, and can be at any time removed.

46. I propose that the shell of the vessel should be made of the lightest material consistent with strength; the hulls to be built in three distinct compartments, with bow and stern bulkheads placed one-third of the breadth within the stem and stern as supports for the necessary attachments.

The central compartment to be two breadths within the inner bulkheads, and to contain the whole of the machinery and fuel. When it is required to use the vessel as a cargo-boat this machinery to be removed.

47. *Other systems of Towing compared with the Nautilus Tug and Tow-boat.*—With regard to the particular mode of towing vessels and the kind of connexion which experience has proved to be convenient and safe, I consider that it is not expedient to articulate together the vessels as in the plan adopted on the Indus River by Mr. Bourne, for the following reasons:—

First.—The only power of steering by means of rudders must be on the terminal barge of the train, and must consequently be slow and inefficient in directing the movements of the others.

Second.—The preceding vessel in an articulation not only tows the one which comes after it, but also steers it, by the position which it assumes with regard to it, and consequently in the tortuous channels and amid the cross currents of the Ganges and Burhampootra, there would be no power of independent action, to allow each vessel to take care of itself.

48. In the system of towing introduced by me in the 'Assam' steamer, and

now proposed for the Nautilus flotilla, the tug and tow-boats are to be connected together in such a way that the pivot of the tugging post is placed at least half the breadth before the stern of the steamer, while the tow-boat had a second centre of motion, connected by a rigid spar with the pivot, and situated at a point in advance of the cutwater. The tugging post or pivot of the tow-boat is made in the form of a timber knee, placed as a bowsprit, and provided with two rollers for supporting the connecting hawsers.

49. There is by this means established between the various barges of a river train, the only kind of connexion which admits of sufficient independent action for each boat to guide itself in an emergency, and is at the same time strong enough to withstand the strain thrown upon them.

The steering apparatus is also arranged with the view of independent action; each boat is to be provided with two rudders, one occupying the position of the dead-wood aft, and the other occupying that of the gripe, forward; the joint action of these balanced rudders enabling each boat to turn on the centre of her length. By using the foremost rudder across the stem, the bow of the boat can be made to follow the stern of the steamer without impeding the movements of the latter to port or starboard, when turning herself.

50. The rapidity with which a boat of this description can be manœuvred by means of fore-and-aft rudders is easily explained. When the stern rudder only is used, the vessel turns upon a pivot situated a short distance forward of the stern post; while, if the bow rudder only is used, the boat tends to turn on a pivot considerably abaft of the bow. Consequently when both rudders are used simultaneously, the common centre of motion will be near the middle of the length of the vessel; on trial, the 'Assam' steamer turning short round in 15 seconds.

51. By turning on this centre it is evident that neither bow nor stern will have as far to move in turning round as if the pivot were situated near either of the extremities, as happens when only one rudder is used. The peculiarity of the mode of connexion is, that while the radial spar, forked at one end, prevents collision between the bow of the tow and the stern of the tug: the distance between them can be at any time increased by means of the hawsers, one of which belongs to each vessel, and by hauling up which the crews of either boat can slack out or take in, as the occasion may require.

52. *Necessity for greater care as to displacement, weight of hull, and capability for cargo at light draft of water. To be secured by a more correct and definite system of contracting for steamers, with specific calculated quantity, by a tabular form of tender.*—From inattention to the necessity of obtaining correct estimates as to the weight of the vessel and calculations of displacement, the majority of the steamers sent from this country under terms of general capability for the navigation of the Indian rivers, have been found to draw a great deal more water than was either specified or contracted for.

53. With the view of ensuring accuracy in this respect, I have used a form of tender for quantities, that was submitted, for the consideration of the contractors and shipbuilders with the view of facilitating the calculations of the quantities to be inserted in the blank tabular form of tender.

The quantities given were not intended to be taken as absolutely correct, but only as approximations to be verified by the contractors themselves, who were requested to state their own quantities with the same form and specific detail.

The calculation of the displacement, however accurate it may be, only gives one of the elements for determining the draft and capability for dead-weight cargo; to arrive at anything like certainty with regard to these two essentials of river navigation, the *weight of the vessel* must be calculated with the greatest care and minuteness.

54. In the estimates received by the Assam Company for an iron tea-boat of 75 feet in length and 12 feet in breadth, the weight of the hull appeared to vary from 17 tons to 10 tons. Much of this was, no doubt, attributable to variations in the thickness of the metal plates, prepared by different methods of construction.

55. Tenders were sent to the office in the usual routine, and others were requested by the Directors from experienced shipbuilders submitting a specification, and to some a tracing of the best boat employed by the Company, with suggestions for increasing the length from 68 to 75 feet, with fittings adapted to navigation by native crews. The five tenders received for the iron hull packed for shipment varied from £300 to 72 per cent. increase of cost, the former being the net price contracted for, the latter a price per ton, builders' measurement, and not including pumps and capstan, these admitting of an indefinite extra charge. The cost of the same vessel by the two contractors would differ 100 per cent.

Having issued the construction form of tender, with specification, and calculated quantities of displacement, weights, and capabilities for cargo, they were verified and reconsidered, after consultation, by several experienced shipbuilders, so as to secure a very great reduction in the weight of the hull, and consequent increase of cargo at light draft: the contract price of different builders only varied 4 per cent. The amended specifications also reduced the weight of hull 25 per cent., increasing the capability for cargo at 2 feet draft 50 per cent.

57. From careful observation, there are many experienced shipbuilders and naval architects who are now competent to undertake contracts, not as formerly, by register tonnage and nominal horse-power at so much per ton of register, but in terms of capability and speed. Such we know to be the case, and with admirable results, in Liverpool, London, the Clyde, and other ports.

58. The exceeding diversity of opinion, and the anomalies of practice, with regard to the requirements of steam-ships and mode of contracting for them, may be accounted for by the fact, that the sudden demand for iron steam-vessels called into existence a numerous body of what may be termed *Mushroom Marine Engineers*, who had previously been employed as assistants to engineers, boiler-makers, or contractors. It is to such men that we are indebted for the luminous discussions on the "Formula" of resistanc, power, and speed of steamers, one of whom propounded as a fixed princple, that naval architects had nothing to do but provide displacement at a given area of section, and that the speed did not depend on the form or lines of the vessel; also that displacement or friction of bottom very little affected the resistance.

59. To such extent has this vague and indefinite style of reckoning proceeded, that there seems to be almost *double entendre* in everything connected with the specification and contracting for steam-vessels. In the first place, there are two meanings attached to the term "tonnage," the *old* and the *new*; then the engine-power is reckoned in nominal and effective horse-power; and the discrepancy which exists between these last-named quantities is scarcely greater than what is found between the *net contract price*, and that which, under accumulated impositions, might come under the name of the *commission price*.

Steam Navigation in England.—The tabular system adopted of estimating the cost of steam transit by the capital required to obtain a ton of capability for cargo, is necessarily different from that in use, as with railway or canal traffic in this country, viz. the cost of a ton per mile, from the absence of all detail of the working expenses, and the conditions of Indian river navigation being so various and totally different from canal or even European river navigation.

The valuable paper read before this Section by Mr. W. H. Bartholomew, the engineer of the Aire and Calder navigation, lucidly illustrated what economic results had been obtained by the system of tug- and tow-boats.

The extraordinary practical results shown by Mr. Bartholomew, are not only honourable to those who, by the combination of practical experience and scientific investigation, have conduced to such important improvements in engines and mode of tugging, but afford the best encouragement to others to persevering inquiry, with the hope of introducing these improvements on the Indian rivers.

The following is a summary of the practical results:—

"A screw steam-tug 64 feet by 11 feet, fitted with its screw and engines, draws 8 or 12 tow-boats of a gross tonnage of 1240 tons, carrying 820 tons of cargo 2¾ miles an hour. Pressure of steam 200 lbs. on the square inch. Two screws on the same shaft, but working in a different plane of rotation, making 180 revolutions per minute. Dynamical effect on tow-rope, 32 cwt.; consumption of coal 2 tons per day, of 10 working hours; draft of water, 6 to 7 feet."

Towing cargo on the Humber, these screw tug-boats can tow and turn eight to twelve barges; experience showing that the addition of two or four vessels reduced the speed very little in proportion to the increase of load, but much depended on steady steering. While on the Bengal rivers, when towing one very long vessel through the tortuous channels, it was found expedient to lash her alongside, keeping their two rudders working together, whenever the length exceeded 180 feet.

Conclusion.—Having had, as commander, builder, and owner of steamers, thirty years' practical experience in the establishing and working the earliest systems of river and ocean steamers in Bengal and the eastern coast of India; and retaining up to the present time a deep personal and pecuniary interest in several local enterprises depending on the development of river steam navigation and maritime trade in Bengal; having also had much experience as Director of companies in this country in contracting for engines and steamers to meet the requirements of the Indian ports,—I believe that the present great difficulty of want of means of transit in India can only be overcome by the immediate construction of steam-tugs and tow-boats for *railway*, but separately for *military and mercantile purposes.*

With a view to effective comparison of the money value of tenders and specifications for river steamers from different builders and contractors, I have used the following Table, by which the capital or cost per ton of capability for weight-cargo can be ascertained at three drafts, as well as the three elements of resistance; from these a scale or curve of displacement and areas can be formed, which with the indicated H. P. will afford the means of ascertaining the *coefficient or index number* of the vessel daily.

DESCRIPTION OF

OF STEAMERS, TU

ESTABLISHE]

ON THE BE:

Comprising shear and deck plans on a s
of their midship sections on a scale
shear and deck plan of the bow and
and Tow Boats, with their special j
with bow and stern rudders acting si

SCALE OF TON:

On the left hand corner of the drawing there are
in the drawings. The perpendicular scale is one of dra
DISPLACEMENT.

The CURVE OF DISPLACEMENT is formed by setting
water in feet, and the calculated displacement in tons at
from those points, perpendicular to their respective scal
until the horizontal water line crosses the perpendicula
points of intersection will enable the displacement due t
aid of calculation.

The name of the vessel to which it belongs is wri
scale where the light draft of each vessel is indicated w
zontal or tonnage scale the name of the vessel is writte
of displacements at the 3 feet load line. The tonnage d

The CAPABILITY FOR DEAD WEIGHT CARGO, marked
ment at the light draft water line in tons from that indi

On the DIAGRAM OF MIDSHIP SECTIONS the displa
lines of each vessel whose light draft is less than 2 feet.
is marked in dotted lines and the weight of the hull belc

On the DECK PLANS are recorded the Medium He
External Bulk, and the Ratio between them, or the num
There is also given the capability for dead weight cargo
vessel, recorded below the dotted line (on the midship s
3rd feet draft water lines. FINANCE (on the deck plan)-
ton of capability for weight cargo, shewing how the cost

Assam Tug and Tow Boat, capital expended
Loaded to 4 ft. C. W. C., 231 tons, capital ...
,, 3 ft. ,, 100 tons, capital ...

Ganges Steam Company, 5 large st
Patna and { C.W.C. 140 tons, cost £81 per ton
Benares { ,, 23 tons, cost £568 capabi

NAUTILUS FLOTILLA OF STEAM TUG AND THR

At the lower part of the drawing there is a shear

CONSTRUCTION FORM OF TENDER.

Tabular Statement of Dimensions, Tonnage, and Calculated Quantities for Bengal River Steamers.

Dimensions.	Tonnage.	Draft of Water, with Resistances at each foot immersed. Dt. Displacement. Area of Midship Section. S. B.—Surface of bottom immersed, in square feet.			
Length over all...... ft. ins. Breadth extreme ... ft. ins. Depth of Hold...... ft. ins.	Old or builder's........... tons New or register........... tons Space internal ...... cubic feet				
At Load Water-line, draft 4 feet. Length .... ft. } Ratio Breadth .... ft. } Height of deck...... ft. } Ratio Medium .... }	Bulk external to the medium height of tonnage of deck above bottom cubic feet or tons displacement.	At 1 foot draft. Dt.......... tons Area ...... sq. ft. S. B. ...... sq. ft.	At 2 feet draft. Dt.......... tons Area ...... sq. ft. S. B. ...... sq. ft.	At 3 feet draft. Dt.......... tons Area ...... sq. ft. S. B. ...... sq. ft.	4 feet at extra load draft. Dt.......... tons Area ...... sq. ft. S. B. ...... sq. ft.
Power and Weight of Engines. Nom. H.P. Indicated H.P. Cylinder diam. in. Stroke in. Ar. Fire Gr. ft. Stm. Ps. lbs.	Weight of Hull. Iron frame, fastenings, beams, and bulkheads } tons	Light Water-line, as calculated. Draft...... ft. in. Dt. .... tons Area sec.... feet	Capability for Weight-cargo, deduced from Displacement, less that due to Weight of Hull and Engines.		
Engine and Machinery ... Boilers, funnel, and fittings tons Water in boilers........... Coal or fuel for hours tons	Wood decks, cabins, &c. and towing gear ...... } Anchors, masts, & fittings Provisions, stores, & crew	Construction Load Water-line. Draft...... ft. in. Dt. .... tons Area sec.... feet	tons.	tons.	tons.
Total weight of Engines .. tons	Total weight of vessel ... tons	Capital or cost per ton of capability.			

This Tabular Form of particulars, with returns of the consumption of coal and speed realized, furnished by ship-owners, would greatly increase our means of obtaining "*the record of facts of the performance of vessels at sea*," so long a desideratum of the shipping committees of the British Association for the Advancement of Science.

Report of the Belfast Dredging Committee. By GEORGE C. HYNDMAN.

FOR the purpose of carrying out the investigation of the Marine Zoology of the coasts of Antrim and Down, the Committee named at the meeting of the British Association held in Dublin last year proceeded to make arrangements early in the present summer. Dr. Dickie and Edward Waller, Esq., repaired to Larne, county Antrim, where they remained for a fortnight during the month of June, accompanied by the writer for the greater portion of the time. Some difficulty was experienced from the want of boats and boatmen. Eventually a yawl, with a crew of five men, was ordered from Groomsport, county Down, and on the 23rd of June a steamer was hired and brought from Belfast by Mr. Patterson.

With these means for work, the following portions of the coast were explored:—

1st. The shallow water lying between the small islands called "The Maidens" and the shore as far north as Ballygalley Head.

2nd. The northern shore of Island Magee, including Brown's Bay and "The Cod-bank," lying north of the Isle of Muck.

3rd. Larne Lough.

4th. The deep water outside the Maidens' Lighthouses.

5th. The Turbot-bank and the deep water adjacent.

A small basketful of the sand procured from the Turbot-bank was forwarded to J. Gwyn Jeffreys, Esq., and a list of its contents made out by him, amounting to 127 species of Testacea in that small quantity of sand. Among these are several very rare shells—a few of them new to the British list, and several to the Irish.

The weather was in general unfavourable, and interfered very much with the operations. Among the submarine rocks off the Lighthouses, where the depth was from 80 to 100 fathoms, the current ran with such strength and rapidity that the dredges got foul several times, and were recovered with great difficulty and loss of time. For further exploration in that quarter some better mode of procedure would require to be adopted.

Dr. Dickie having now been obliged to leave us for Aberdeen, Mr. Waller took lodgings at Groomsport in order the better to continue the investigation, and, along with the writer, made a number of excursions in different directions.

1st. Across Belfast Bay, between the Copeland Islands on the south and Black Head on the north.

2nd. Outside the entrance of Belfast Bay, eastward, into 60 fathoms depth, and across to the Copelands.

3rd. Off Black Head and along the Gobbins as far as the Isle of Muck, including the Turbot Bank.

4th. The shores of the Copeland Islands and Groomsport, with the Sound between the Islands and the coast of Down.

5th. A submarine bank, composed of coarse stones, broken shells, and mud, with a number of living Mollusca, lying south of the Copeland Islands, a mile south of Donaghadee, and about a mile from shore, in 20 fathoms water, and called "The Riggs" by the fishermen, who are in the habit of setting their long lines there.

From the extent of the area indicated by the boundaries above mentioned, it must be evident that the portion passed over by our dredges must be comparatively very small, and that the lists of species enumerated can only be taken as an approximation to the whole number in the region. The dead shells far exceed the living in number, the latter being for the most part sparingly scattered, except in the case of a few gregarious species.

Lists are appended of the species obtained from the different dredgings, from which it will be seen that since last year the following have been added:—

A. Arctic. N. Northern. S. Southern.

S. Pholadidea papyracea. Discovered in the dredgings of 1857, imbedded in rolled lumps of hard clay, and again in the deep water this season. Recorded by the late W. Thompson as found at Portrush by the Ordnance Survey Collectors.
S. Lepton nitidum. Turbot-bank sand, Mr. Waller; new to the Irish list.
S. Montacuta ferruginosa. Turbot-bank sand, Mr. Waller. Recorded by the late W. Thompson, Dublin coast and south of Ireland.
S. Nucula tenuis. Living in deep water, Maidens, Mr. Hyndman. Recorded by the late W. Thompson; Mr. Warren, Portmarnock.
S. Argiope cistellula?, living. This interesting addition to the Irish fauna was first discovered by Mr. Hyndman in the dredgings of 1857, and again taken by the party in 1858. It seems to be abundant on dead bivalves incrusted with Serpulæ.
Terebratula capsula, living. This new species, taken with the foregoing, proves to be the same as the shell found by Mr. Norman at Plymouth, and named by Mr. Jeffreys in the 'Annals of Nat. Hist.' for January 1859.
N. Margarita undulata (Sowerby). Turbot-bank sand, Mr. Jeffreys; new to the Irish list.
N. —— pusilla ( ). Turbot-bank sand, Mr. Jeffreys; new to the Irish list.
N. —— cinerea (Couthouy). Turbot-bank sand, Mr. Jeffreys; new to the Irish list.
Rissoa soluta. Turbot-bank sand, Mr. Jeffreys.
Skenea divisa. Turbot-bank sand, Mr. Jeffreys.
Cerithium niveum (Lovén), dead. This interesting addition to the British list was determined by Mr. Jeffreys from the Turbot-bank sand.
Scalaria Eschrichti (Holböll), dead. In Turbot-bank sand, Mr. Waller, 1857. Described by him in the 'Transactions of the Royal Dublin Society,' and named provisionally *Turritella Hibernica*, but now ascertained by Mr. Jeffreys to be the *Scalaria* mentioned. Recently discovered by Mr. Jeffreys "in the collection of Mr. Macculloogh of Guernsey, picked up on the beach at Herm together with other undoubtedly British shells."
N. Eulimella Scillæ, dead. Turbot-bank sand, Mr. Waller and Mr. Hyndman.
—— acicula, dead. Turbot-bank sand, Mr. Waller and Mr. Jeffreys.
Chemnitzia rufa, dead. Turbot-bank sand, Mr. Jeffreys.
—— scalaris, dead. Turbot-bank sand, Mr. Jeffreys.
—— interstincta, dead. Turbot-bank sand, Mr. Jeffreys.
Odostomia dubia, dead. Turbot-bank sand, Mr. Jeffreys.
—— nitida, dead. Turbot-bank sand, Mr. Jeffreys.
—— rissoides, dead. Turbot-bank sand, Mr. Jeffreys.
—— cylindrica, dead. Turbot-bank sand, Mr. Jeffreys.
—— insculpta, dead. Turbot-bank sand, Mr. Jeffreys.
—— decussata, dead. Turbot-bank sand, Mr. Jeffreys.
—— truncatula, dead. Turbot-bank sand, Mr. Jeffreys. Plymouth Sound is the only other known locality of this shell.
A. Natica clausa, dead. Turbot-bank sand, Mr. Jeffreys.
A. Trophon scalariformis, dead. Turbot-bank sand, Mr. Jeffreys; new to the British list.
Mangelia Trevelliana, dead. Turbot-bank sand, Mr. Jeffreys.
—— Leufroyi, dead, but very fresh. Turbot-bank sand, Mr. Hyndman and Mr. Waller.
—— scabra, dead. Turbot-bank sand, Mr. Jeffreys.
Buccinum cyaneum. A fragment only, considered by Mr. Jeffreys to be this species, in Turbot-bank sand, Mr. Waller.
Cylichna mammillata, dead. Turbot-bank sand, Mr. Waller.
—— umbilicata, dead. Turbot-bank sand, Mr. Waller.

The interesting question, however, still remains undetermined, as to whether these Northern species may be considered as still living in this region, or as having been washed out of some submerged pleistocene bed. Upon this point I feel myself incompetent to offer a decided opinion without further investigation, but would refer to the observations on the subject published by Mr. Jeffreys in the 'Annals of Natural History' for August 1858, and by Mr. Waller in the 'Transactions of the Royal Dublin Society.'

for March 1858. I may also quote an extract from a note of Mr. Jeffreys of the 13th September, showing his latest views:—"I found, in the dredged sand from the Turbot-bank, two or three shells or fragments which appear to belong to *Cerithium reticulatum*; but they are evidently *fossil*, and as completely mineralized as a *Euomphalus* from the mountain-limestone. This fact is interesting, and may be, I think, considered fair ground for an inference that the other shells found with these fossils (being in a totally different condition) are recent."

Dr. Kinahan, of Dublin, having lately visited Belfast, took the opportunity of inspecting the late William Thompson's collection of Crustacea, and some private collections. He has kindly furnished a list of the species he observed, and corrected some mistakes in the names, and has also added to our list a new *Crangon*, which he has named *Pattersonii*.

North of Larne Lough, two miles from land, one mile south of Ballygalley Head. Depth 15 to 25 fathoms:—

Clavellina lepadiformis, living.
Saxicava rugosa, living, several.
Corbula nucleus, living, few.
Solen pellucidus, living, one.
Psammobia tellinella, dead, few; living, very few.
Tellina crassa, dead, one.
Syndosmya intermedia, dead, several.
Mactra elliptica, living, one.
Tapes virginea, living, many.
Venus striatula, living, one.
—— ovata, dead, many.
—— fasciata, dead, several.
—— casina, dead, several (Messrs. Kane and Smith).
Circe minima, dead, one.
Astarte sulcata, living, several.
—— triangularis, dead, several.
Cardium echinatum, dead, one.
—— fasciatum, dead, several.
—— pygmæum, dead, several; living, one.
Lucina borealis, dead, one.
Crenella marmorata, dead, one.
—— decussata, living, many.
Nucula nucleus, living, several.
Pectunculus glycimeris, dead, but valves united and quite fresh; very abundant, in 10 to 12 fathoms, at Ballygalley; their death probably owing to deposits from peat-bogs carried down by rivulets (Dr. Dickie).
Pecten tigrinus, dead, several.
Pecten opercularis, living, several.
Ostrea edulis, living, one: very old, with a Terebratula upon it.
Anomia ephippium, living, many.
Terebratula caput-serpentis, living, two.
Chiton ruber, living, several.
—— asellus, living, several.
Acmæa virginea, living, several.
Emarginula reticulata, living, several.
Turritella communis, dead, one (Messrs. Kane and Smith).
Trochus zizyphinus, living, many.
—— millegranus, dead, several.
—— Montagui, living, one.
—— tumidus, living, many.
—— cinerarius, living, many.
—— magus, dead, one.
Littorina littorea, dead, one.
Lacuna puteolus, dead, one.
Rissoa parva, dead, many.
—— costata, dead, a few.
—— striata, dead, many.
Natica nitida, living, several.
Lamellaria perspicua, dead, one.
Buccinum undatum, living, several.
Mangelia turricula, dead, one.
Cypræa Europæa, dead, several; living, one.
Cylichna cylindracea, dead, one.
—— obtusa, dead, several.

Cod Bank, three miles north from Isle of Muck, and two from entrance of Larne Lough. Depth, 20 fathoms or more. Bottom: gravel, stones, and broken shells:—

Aplidium fallax, living, few.
Clavellina lepadiformis, living, very few.
Saxicava rugosa, living, many.
—— arctica, living, few.
Mya arenaria, dead, few.
—— truncata, dead, few.
Corbula nucleus, dead, many; living, several.
Thracia villosiuscula, dead, few.
Cochlodesma prætenue, dead, one; single valve.
Solen ensis, dead, very few.
—— siliqua, dead, very few.
Solen pellucidus, living, very few.
Psammobia Ferroensis, dead, one.
—— tellinella, dead, many; living, few.
Tellina crassa, living, one.
—— donacina, living, one.
Syndosmya prismatica, dead, very few.
Mactra elliptica, living, few.
Tapes virginea, dead, many; living, many.
Venus casina, dead, many; living, few.
—— fasciata, dead, many; living, many.
—— ovata, dead, common; living, common.
Artemis lincta, living, very few.

Artemis exoleta, dead, one.
Cyprina Islandica, dead, one; living, one.
Circe minima, dead, few; living, very few.
Astarte triangularis, dead, very few.
—— sulcata, living, many.
Cardium fasciatum, living, several.
—— pygmæum, dead, very few.
—— Norvegicum, dead, several.
Lucina borealis, dead, several.
Modiola modiolus, living, many.
Crenella marmorata, dead, one.
—— decussata, dead, few.
Nucula radiata, dead, one; living, one.
—— nucleus, living, many.
Leda caudata, dead, several; living, one.
Pectunculus glycimeris, dead, many; living, few.
Lima Loscombii, dead, several.
Pecten pusio, dead, one.
—— tigrinus, dead, many; living, several.
—— maximus, dead, many; living, very few.
—— opercularis, living, many.
Ostrea edulis, dead, many.
Anomia ephippium, living, many.
—— striata, living, very few.
—— patelliformis, dead, one.
Chiton ruber, living, very few.
—— asellus, living, many.
Acmæa virginea, living, many.
Dentalium entalis, dead, very few.
Fissurella reticulata, living, one.
Emarginula reticulata, dead, many; living, many.
Trochus zizyphinus, living, many.
—— var. Lyonsii, living, one.
—— millegranus, dead, many; living, few.
—— tumidus, living, very few.
—— Montagui, dead, very few.
—— cinerarius, living, few.
Phasianella pullus, living, few.
Lacuna vincta, dead, very few.
—— crassior, dead, few.
Rissoa striata, dead, many.
Rissoa (other species, not determined).
Turritella communis, dead, few.
Aporrhaïs pes-pelecani, dead, few; living, few.
Natica nitida, dead, several; living, very few.
—— Montagui, living, two.
Nassa incrassata, living, very few.
Buccinum undatum, dead, several.
Fusus Islandicus, dead, one.
Trophon clathratus, living, two.
—— muricatus, living, one.
—— Barvicensis, living, two.

Larne Lough, 1 to 2½ miles from the entrance. Depth, 4 to 5 fathoms. Bottom chiefly nullipore, with occasionally mud, sand, and broken shells:—

Mya arenaria, dead, several.
Corbula nucleus, dead, many; living, few.
Solen siliqua, dead, few.
—— pellucidus, living, very few.
Psammobia Ferroensis, dead, few.
—— tellinella, dead, few.
Syndosmya intermedia, dead, very few; living, very few.
Tapes virginea, dead, many; living, few.
—— pullastra, dead, few.
Venus striatula, dead, few.
—— fasciata, dead, few; valves double.
—— ovata, dead, many; living, very few.
Cyprina Islandica, dead, very few; fragments.
Cardium echinatum, dead, very few; living, one.
—— pygmæum, living, very few.
—— Suecicum, dead, very few.
Lucina borealis, dead, few.
Crenella decussata, living, one.
Nucula nucleus, dead, many.
Pectunculus glycimeris, dead, very few.
Pecten opercularis, dead, few.
Ostrea edulis, dead, very few.
Trochus cinerarius, living, many.
Turritella communis, dead, few.
Buccinum undatum, dead, many.
Cypræa Europæa, dead, few.

Brown's Bay, Island Magee, from 4 fathoms outside, to close in shore:—

Corbula nucleus, living, few.
Thracia villosiuscula, dead, one.
Solen ensis, dead, one.
Psammobia Ferroensis, dead, one.
Tellina incarnata, dead, several; old single valves.
—— fabula, dead, several.
Syndosmya alba, dead, few.
—— prismatica, dead, few.
Donax anatinus, living, one.
Mactra subtruncata, living, few.
Lutraria elliptica, dead, one.
Tapes pullastra, dead, one.
Venus striatula, living, few.
Artemis lincta, dead, few.
—— exoleta, dead, few.
Cyprina Islandica, dead, one; living, one, young.
Cardium pygmæum, dead, one.
Lucina borealis, dead, one.
Nucula nitida ?, living, few.
Leda caudata, dead, one.
Turritella communis, dead one.

21st June, 1858.—Between the Maidens' Lighthouses and the Isle of Muck, in about 20 fathoms:—

Molgula tubulosa, living, several.
Cynthia morus, living, several.
Saxicava rugosa, dead, few.
Corbula nucleus, dead, few.

Pandora obtusa, dead, one.
Tellina crassa, dead, one.
Mactra elliptica, dead, one, double.
Tapes virginea, dead, several.
Venus casina, dead, many.
—— fasciata, living, one.
—— ovata, living, several.
Artemis exoleta, dead, one.
—— lincta, dead, one.
Astarte sulcata, living, several.
Cardium edule, living, one, small size.
—— pygmæum, living, few.
—— fasciatum, living, several.
Modiola modiolus, dead, several.
Nucula nucleus, dead, several; living, several.
Leda caudata, dead, several.
Pectunculus glycimeris, dead, many; living, few.
Lima Loscombii, living, one.
—— subauriculata, dead, several.
Pecten pusio, dead, several.
—— tigrinus, dead, many; single valves.
Pecten opercularis, dead, several.
Anomia ephippium, dead, few.
Terebratula caput-serpentis, dead, several; living, few.
Crania anomala, dead, several.
Chiton cancellatus, living, few.
Dentalium entalis, living, several.
Pileopsis Hungaricus, living, one.
Emarginula reticulata, dead, several.
Trochus zizyphinus, living, many.
—— millegranus, living, few.
—— tumidus, dead, one.
—— cinerarius, living, one.
Turritella communis, dead, one.
Natica Montagui, living, few.
—— nitida, living, few.
Murex erinaceus, dead, one.
Nassa incrassata, dead, many; living, one.
Trophon clathratus, dead, few.
Cypræa Europæa, dead, few.
Dendronotus arborescens, living, few.

21st June, 1858.—In a day's dredging east and south-east of the Maidens' Rocks, off Larne, in from 70 to 90 fathoms, the operations having been very much impeded by the strong currents, and the dredge catching on the rocks at such a depth, the following species were obtained:—

Pholadidea papyracea, living, one; very small, in hard clay.
Saxicava arctica, dead, few; living, several.
—— rugosa, living, several.
Corbula nucleus, living, several.
Solen siliqua, dead, one; fragment.
Tapes virginea, dead, several; living, one.
Venus casina, dead, several.
—— ovata, dead, several; living, few.
Lucinopsis undatus, dead, one.
Astarte sulcata, living, several.
Cardium fasciatum, living, few.
—— pygmæum, dead, few; living, few.
Mytilus edulis, dead, several; single valves.
Modiola modiolus, dead, several; living, several.
—— phaseolina, living, several.
Crenella marmorata, living, few.
Nucula nucleus, dead, few; living, several.
Leda caudata, dead, several.
Pectunculus glycimeris, dead, few.
Lima Loscombii, living, one.
—— subauriculata, dead, one.
Pecten pusio, dead, few; living, two, small size.
—— striatus, living, one.
—— tigrinus, dead, several; living, few.
—— opercularis, dead, several.
Anomia ephippium, living, several.
—— aculeata, dead, several.
—— patelliformis, living, few.
Terebratula caput-serpentis, dead, several; living, several.
Crania anomala, dead, several.
Chiton Hanleyi?, living, one.
—— cancellatus, living, few.
Propilidium ancyloide, living, one.
Dentalium entalis, living, several.
Pileopsis Hungaricus, dead, several.
Emarginula reticulata, dead, several; living, few.
—— crassa, dead, one.
Trochus zizyphinus, living, several.
—— millegranus, living, several.
—— tumidus, living, few.
—— cinerarius, living, one.
Natica nitida, dead, several; living, one.
—— Montagui, living, few.
Velutina lævigata, living, few.
Nassa incrassata, dead, many; living, one; dead mostly with Paguri.
Buccinum undatum, dead, several; living, several, very young.
Fusus Islandicus, living, one.
—— antiquus, living, one.
Trophon clathratus, dead, one; living, several.
Cypræa Europæa, dead, few.
Dendronotus arborescens, living, several.

CRUSTACEA.

Hyas coarctatus, few.
Eurynome aspera, one.
Portunus depurator, several.
Ebalia Pennantii, two.
Pagurus Bernhardus, many.
—— Prideauxii, two.
—— Thompsoni, several.
Galathea nexa, two.
Pandalus annulicornis, several.

CIRRIPEDIA.

Balanus porcatus, dead, valves.

ECHINODERMATA.

Ophiura albida, few.
Ophiocoma bellis, few.

Ophiocoma rosula, few.
Cribella oculata, two.
Solaster papposa, few.
Palmipes membranaceus, one, very small.
Echinus sphæra, one.
Echinocyamus pusillus, many.
Amphidotus roseus, few.
Thyone papillosa, two.
Sipunculus Bernhardus, few.

POLYZOA.

Tubulipora patina, few.
—— serpens, few.
Crisia eburnea, few.
Lepralia, various species, not yet determined.
Cellularia reptans, few.
Flustra foliacea, many.
—— truncata, few.
—— avicularis, few.
Salicornaria farcimoides, few.
Alcyonidium gelatinosum, few.

HELIANTHOIDA.

Cyathina Smithii.
Adamsia maculata.

ASTEROIDA.

Alcyonium digitatum.

HYDROIDA.

Tubularia indivisa, many.
—— larynx, many.
Halecium Beanii, few.
Sertularia rugosa, two.
—— rosacea, many.
—— tamarisca, two.
—— abietina, many.
—— argentea, many.
Antennularia antennina, few.
Plumularia falcata, many.
Laomedea ——?, parasitical upon Tubularia.

Turbot Bank. On the 22nd June some exploration was effected, and on the 23rd a steamer was engaged from Belfast, when a quantity of material was obtained from the Bank and the deep water adjacent. After the copious list published in the Report of the British Association for 1857, it would be needless to repeat the whole of the species obtained during the present season; but in order to show the richness of the deposit, a list is here given of the contents of a small basketful of the shell-sand forwarded to J. Gwyn Jeffreys, Esq., and communicated by him as follows:—

List of Testacea found by J. Gwyn Jeffreys, Esq., in dredged sand from the Turbot Bank near Belfast Bay.

A. Arctic. N. Northern. S. Southern.

Saxicava rugosa.
Corbula nucleus.
Pandora obtusa.
Thracia villosiuscula.
Psammobia tellinella, living.
—— costulata, a single valve.
Mactra elliptica, living.
Tapes pullastra.
—— virginea.
Venus casina.
—— striatula.
—— fasciata, living.
—— ovata.
Artemis exoleta.
—— lincta.
Circe minima.
Astarte sulcata.
—— triangularis, living.
Cardium echinatum.
—— punctatum (nodosum).
—— fasciatum.
Lucina borealis.
—— spinifera.
Montacuta ferruginosa.
—— bidentata.
Modiola modiolus.
—— phaseolina.
N. Crenella decussata, living.
Nucula nucleus.
Leda caudata.
Arca tetragona.
Pectunculus glycimeris.
Lima subauriculata.
—— Loscombii.
Pecten varius.
—— pusio.
—— tigrinus.
—— opercularis.
Ostrea edulis.
Anomia ephippium.
Terebratula caput-serpentis.
N. Crania anomala.
Patella vulgata.
Acmæa virginea.
N. Propilidium ancyloide.
Dentalium entalis.
N. Puncturella Noachina.
Fissurella reticulata.
Emarginula reticulata.
Trochus zizyphinus.
—— millegranus.
—— Montagui.
—— tumidus.
—— cinerarius.
—— magus.
N. T. (Margarita) undulatus.
T. (Margarita) pusillus.
Phasianella pullus.
S. Adeorbis subcarinata.
Littorina rudis.

Littorina littoralis.
Lacuna pallidula.
—— puteolus.
—— vincta.
—— crassior.
S. Rissoa striatula.
S. —— crenulata.
—— Beanii.
—— punctura.
—— costata.
—— striata.
—— parva.
—— inconspicua, var. albida.
—— semistriata and var. alba.
—— cingillus and var. rupestris.
—— soluta.
Skenea planorbis.
—— divisa.
Turritella communis.
Aporrhaïs pes-pelecani.
Cerithium reticulatum.
—— adversum.
Eulima polita.
—— distorta.
—— bilineata.
S. Chemnitzia elegantissima.
S. —— rufa.
S. —— scalaris.
—— interstincta.
—— indistincta.
Odostomia unidentata.
—— plicata.
—— eulimoides.
—— dubia.
—— nitida.
—— rissoides.
—— cylindrica.
Odostomia insculpta.
S. —— truncatula (one specimen). Plymouth Sound is the only other known locality.
—— spiralis.
—— decussata.
Eulimella acicula.
Natica nitida.
—— Montagui.
A. —— clausa (young); has the umbilicus entirely closed.
Velutina lævigata.
N. Trichotropis borealis.
Cerithiopsis tubercularis.
Murex erinaceus.
Purpura lapillus.
Nassa incrassata.
—— reticulata.
Buccinum undatum.
—— Holböllii.
Fusus Islandicus.
—— antiquus.
Trophon clathratus.
A. —— scalariformis.
S. —— muricatus.
—— Barvicensis.
Mangelia Trevelliana.
—— rufa.
—— Leufroyi.
—— linearis.
—— scabra.
—— costata.
—— septangularis.
Cypræa Europæa.
Cylichna truncata.

(In all 129 species.)

23rd June, 1858.—Turbot Bank. In addition to the foregoing, the following species have also been since determined, not hitherto recorded from this locality, including the deep water adjacent.

Lepton nitidum, living, Mr. Waller.
Arca lactea, dead, Mr. Waller.
*Emarginula rosea, dead, Mr. Waller.
Rissoa vitrea, dead, Mr. Waller.
*Skenea costulata, dead, Mr. Waller.
Scalaria Eschrichti, dead, Mr. Waller.
Aclis supranitida, dead, Mr. Waller.
Odostomia unidentata, var. turrita, dead, Mr. Waller.
—— alba and var., dead, Mr. Waller.
Odostomia Warrenii, dead, Mr. Waller.
—— excavata, dead, Mr. Waller.
*Eulimella affinis, dead, Mr. Waller.
—— Scillæ, dead, Mr. Waller.
*Cerithiopsis pulchella, dead, Mr. Waller.
Nassa pygmæa, living, Mr. Waller.
Buccinum cyaneum, dead, 1857, Mr. Waller.
Cylichna mammillata, dead, Mr. Waller.
—— umbilicata, dead, Mr. Waller.

16th August, 1858.—On this day Mr. Waller and Mr. Hyndman dredged over the entrance to Belfast Bay from Groomsport to Whitehead, thence out eastward into 60 fathoms, and found only mud and sand with dead and broken shells, containing nothing worthy of record except a few specimens of *Emarginula crassa* of large size, but dead and damaged, and a single living specimen of the same of small size. On returning, when off the Copelands, in 40 fathoms, a single broken example of *Mangelia Leufroyi* occurred.

On the 18th August they were occupied in dredging in 25 fathoms about two miles off Black Head, in a line with the Copeland Light. A quantity

* New to the Irish list.

of shell-sand was procured here, not yet fully examined; but, at present, the following species of shells have been made out:—

Saxicava rugosa.
Corbula nucleus.
Pandora obtusa.
Thracia phaseolina.
—— villosiuscula.
Solen pellucidus.
Psammobia Ferroensis.
Syndosmya alba.
—— prismatica.
Mactra elliptica.
Tapes virginea.
Venus fasciata.
—— striatula.
—— ovata.
Artemis exoleta.
—— lincta.
Cyprina Islandica.
Astarte sulcata.
—— triangularis.
Cardium fasciatum.
—— pygmæum.
—— echinatum.
—— nodosum.
Lucina borealis.
—— flexuosa.
Montacuta ferruginosa.
—— bidentata.
—— substriata.
Lepton nitidum.
Modiola modiolus.
—— phaseolina.
Crenella discors.
—— marmorata.
—— decussata.
Nucula nucleus.
—— nitida.
—— radiata.
Leda caudata.
Pectunculus glycimeris.
Lima subauriculata.
—— Loscombii.
Pecten opercularis.
—— pusio.
—— tigrinus.
—— striatus.
—— similis.
—— maximus.
Ostrea edulis.
Anomia ephippium.
—— striata.
Terebratula caput-serpentis.
Patella pellucida.
Acmæa virginea.
Propilidium ancyloide.
Dentalium entalis.
Pileopsis Hungaricus.
Fissurella reticulata.
Puncturella Noachina.
Emarginula reticulata.
Trochus zizyphinus.
Trochus var. Lyonsii.
—— granulatus, fragments.
—— millegranus.
—— Montagui.
—— cinerarius.
—— magus.
—— tumidus.
Phasianella pullus.
Adcorbis subcarinata.
Lacuna crassior.
—— vincta.
Rissoa Zetlandica.
—— crenulata.
—— Beanii.
—— punctura.
—— striata.
—— parva.
—— inconspicua.
Turritella communis.
Aporrhaïs pes-pelecani.
Cerithium reticulatum.
—— adversum.
Scalaria clathratula.
Aclis supranitida.
Eulima polita.
—— bilineata.
—— distorta.
Chemnitzia elegantissima.
—— indistincta.
—— rufescens.
Odostomia truncatula.
—— interstincta.
—— spiralis.
Eulimella Scillæ.
Natica monilifera.
—— nitida.
—— Montagui.
Velutina lævigata.
Trichotropis borealis.
Cerithiopsis tubercularis.
Murex erinaceus.
Nassa reticulata.
—— incrassata.
Buccinum undatum.
Fusus antiquus.
—— Islandicus.
Trophon clathratus, living.
—— muricatus, living.
—— Barvicensis, living.
Mangelia turricula, living.
—— Trevelliana.
—— rufa.
—— septangularis.
—— linearis.
—— costata.
Cypræa Europæa.
Ovula acuminata.
Cylichna obtusa.
Scaphander lignarius.

4th and 13th September, 1858.—On a bank called "The Riggs," lying south of the Copelands, about a mile south of Donaghadee, and a mile from land, in about 20 fathoms (the bottom, sand, stones, and broken shells), the following species occurred:—

Saxicava rugosa, living.
Corbula nucleus, living.
Pandora obtusa, living.
Thracia phaseolina, dead.
Solen pellucidus, dead.
Psammobia Ferroensis, dead.
—— tellinella, living.
Syndosmya alba, dead.
—— prismatica, dead.
Mactra elliptica, living.
Tapes virginea, living.
Venus casina, dead.
—— striatula, living.
—— fasciata, living.
—— ovata, living.
Artemis exoleta, dead.
—— lincta, dead.
Cyprina Islandica, dead.
Circe minima, living.
Astarte sulcata, dead.
—— triangularis, living.
Cardium echinatum, dead.
—— fasciatum, dead.
Lucina spinifera, living.
Modiola modiolus, living.
—— phaseolina, living.
Crenella decussata, living.
Nucula nucleus, living.
—— nitida, living.
Leda caudata, living and dead.
Pectunculus glycimeris, living and dead.
Lima subauriculata, dead.
—— Loscombii, living and dead.
Pecten pusio, dead.
—— tigrinus, living.
—— opercularis, living.
—— maximus, living.
—— striatus, living.
Anomia ephippium, living.
Chiton ——, living.
Acmæa virginea, living.
Dentalium entalis, living.
Pileopsis Hungaricus, dead.
Emarginula reticulata, living.
Trochus zizyphinus, living.
—— millegranus, dead.
—— tumidus, living.
—— cinerarius, dead.
Phasianella pullus, dead.
Lacuna crassior, dead.
Turritella communis, dead.
Aporrhaïs pes-pelecani, dead.
Natica nitida, dead.
—— Montagui, dead.
—— monilifera, dead.
Purpura lapillus, dead.
Nassa ——, dead.
Buccinum undatum, living.
Fusus Islandicus, dead.
—— antiquus, living.
Trophon clathratus, dead.
—— muricatus, dead.
Cypræa Europæa, dead.

13th September, 1858.—Four miles from Black Head, in a line with the Copeland Islands, in 15 fathoms; bottom, mud and dead shells, with corallines:—

Saxicava rugosa, living.
Pandora obtusa, living.
Thracia villosiuscula, dead.
Cochlodesma prætenue, dead.
Solen ensis, dead.
—— pellucidus, dead.
Solecurtus coarctatus, dead.
Psammobia Ferroensis, dead.
—— tellinella, living.
Tellina incarnata, dead.
—— crassa, dead.
—— tenuis, dead.
Syndosmya prismatica, dead.
—— alba, dead.
Mactra elliptica, dead.
Tapes virginea, dead.
Venus casina, living.
—— striatula, dead.
—— fasciata, living.
—— ovata, living.
Artemis exoleta, dead.
—— lincta, dead.
Cyprina Islandica, dead.
Astarte sulcata, living.
Cardium echinatum, dead.
—— fasciatum, living.
Cardium Norvegicum, living.
Lucina borealis.
—— spinifera.
Modiola modiolus, living.
—— phaseolina, living.
Nucula nucleus, living.
—— nitida, living.
Leda caudata, dead.
Pectunculus glycimeris, dead.
Lima Loscombii, dead.
Pecten opercularis, dead.
—— tigrinus, dead.
—— similis, dead.
—— maximus, dead.
Ostrea edulis, dead.
Anomia ephippium, dead.
Terebratula caput-serpentis, living.
Chiton ——? living.
Acmæa virginea, living.
Dentalium entalis, living.
Pileopsis Hungaricus, dead.
Emarginula reticulata, living.
Trochus zizyphinus, living.
—— millegranus, dead.
—— tumidus, living.
—— cinerarius, dead.

Trochus magus, dead.
Phasianella pullus, dead.
Lacuna crassior, dead.
Rissoa striata, dead.
—— punctura, dead.
—— —— ?
Turritella communis.
Aporrhaïs pes-pelecani.
Odostomia —— ?
—— —— ?
Natica monilifera, dead.
—— nitida, living.
—— Montagui, dead.
Velutina lævigata, living.
Trichotropis borealis.
Nassa incrassata.
Buccinum undatum, living.
Fusus Islandicus.
Trophon clathratus.
—— muricatus.
Cypræa Europæa, living.
Doris.
Eolis.
Lomanotus.
Eledone cirrhosus, very small.
Scalpellum vulgare, on stems of Antennularia.
Balanus porcatus, dead, but also frequently found living on other occasions.

14th September, 1858.—The weather being too rough for distant work, we sent out the men to dredge in the Sound between the large Copeland and the Lighthouse Islands in 12 fathoms, and procured the following:—

Saxicava rugosa, living, large size; not burrowing.
Mya arenaria, dead.
Corbula nucleus, living.
Mactra elliptica, living.
Syndosmya alba, living.
Tapes virginea, living.
Cyprina Islandica, dead.
Cardium echinatum, dead.
—— Norvegicum, dead.
—— nodosum, living.
Nucula nucleus, living.
—— nitida, living.
Leda caudata, living.
Modiola modiolus, living.
Pecten maximus, living.
—— opercularis, living.
—— tigrinus, dead.
—— pusio, living.
—— striatus, living.
Ostrea edulis, living.
Anomia ephippium, living.
Terebratula caput-serpentis, living.
Chiton —— ?
—— —— ?
Acmæa virginea, living.
Dentalium entalis, dead.
Pileopsis Hungaricus, living.
Emarginula reticulata, living.
Trochus magus, living.
Rissoa parva, living.
Aporrhaïs pes-pelecani, living.
Velutina lævigata, living.
Trichotropis borealis, dead.
Buccinum undatum, living.
Fusus antiquus, living.
Trophon clathratus, dead.
Echinus sphæra.
—— miliaris.
Alcyonium digitatum.
Molgula —— ?

List of Crustacea inhabiting Belfast Bay.
By Professor John Robert Kinahan, *M.D.*, *M.R.I.A.*

Explanatory marks:—D. Specimens obtained by me in 1858. C. In collections. C.S.B. Identified by C. Spence Bate, Esq.

This is made up from the following sources:—(1) Specimens obtained during dredging excursions at Bangor, Groomsport, Holywood, Carrickfergus, Whitehead, Blackhead, and the Gobbins; these species are marked D, and have been all carefully identified. (2) A careful examination of the specimens in the Belfast Museum, most of which are marked in the late Mr. W. Thompson's own hand; in the private collection of Mr. Geo. C. Hyndman; and some few which had been preserved by Edward Waller, Esq. (3) From the specimens obtained by the Ordnance Survey Collectors in 1837–38. And (4) as regards the Amphipoda, chiefly a list of the specimens collected by the late W. Thompson, Esq., and submitted to Mr. Westwood, kindly furnished to me by Charles Spence Bate, Esq., F.L.S., by whom they were identified. The list must be, however, looked on as a mere approximation to a full list of Crustacea, as many of the Amphipoda and Isopoda recorded even in Thompson's lists are purposely omitted, being critical species which have been so imperfectly described as to render their discrimination from kindred species hazardous in the extreme. I have therefore thought it more advisable to pretermit all notice of such species.

D. Inachus Dorynchus. Common at Groomsport.
D. —— Dorsetensis. Rather scarce at Groomsport.
C. —— leptochirus. Collected by Ordnance Survey.
D. Hyas araneus.
D. —— coarctatus.
D. Stenorhynchus phalangium.
D. Eurynome aspera.
C. Perimela denticulata. Belfast Museum.
D. Cancer pagurus.
C. Pilumnus hirtellus. Belfast Museum.
C. Xantho florida. Collected by Ordnance Survey.
D. Portunus puber.
D. —— corrugatus.
D. —— arcuatus.
D. —— depurator.
D. —— pusillus.
D. —— holsatus.
D. Carcinus Mænas.
C. Portumnus variegatus. Belfast Museum.
D. Atelecyclus heterodon.
C. Corystes Cassivelaunus. Belfast Museum.
C. Gonoplax angulatus. Belfast Museum.
C. Pinnotheres pisum. Belfast Museum.
C. Ebalia Pennantii. Belfast Museum.
C. —— Bryerii. Belfast Museum.
C. —— Cranchii. Ordnance Survey.
D. Bernhardus streblonyx.
D. —— Prideauxii.
D. —— Thomsoni.
D. —— Cuanensis.
D. —— Ulidianus.
D. —— Hyndmanni.
D. —— lævis.
D. Porcellana platycheles.
D. —— longicornis.
C. Galathea squamifera. Ordnance Survey.
C. —— nexa. Belfast Museum.
C. —— strigosa. Belfast Museum.
D. —— Andrewsii.
C. Munida Rondeletii. Dredged abundantly by Mr. Hyndman.
C. Palinurus vulgaris. Ordnance Survey.
C. Astacus fluviatilis.
D. Homarus vulgaris.
D. Crangon vulgaris.
D. —— Allmanni. Not in Thompson's list.
D. —— fasciatus. Not in Thompson's list.
D. —— sculptus. Not in Thompson's list.
D. —— spinosus. Not in Thompson's list.
D. —— Pattersonii, n. s. New species, dredged by me off Blackhead.
D. Hippolyte varians.
D. —— Thompsoni. Not in Thompson's list.
D. —— Cranchii. Not in Thompson's list.
D. —— pusiola. Not in Thompson's list.
D. Pandalus annulicornis.
C. Palæmon serratus. Ordnance Survey.
D. —— squilla.
D. Mysis vulgaris.
D. Mysis chamæleon.
C. —— Griffithsii. Belfast Museum. Not in Thompson's list.
C. Cynthilia Flemingii.
C. Macromysis brevispinosa.
C. Diastylis Rathkii.
C. Cuma trispinosa.
D. Talitrus locusta.
D. Orchestia littorea.
D. —— Deshayesii. Not in Thompson's list. New to Ireland.
D. —— lævis. Not identified in Thompson's list.
C.S.B. Montagna monoculoides. Belfast Museum.
C.S.B. Lysianassa costæ. Belfast Museum.
C.S.B. —— longicornis. Belfast Museum.
C.S.B. Anonyx minutus. Belfast Museum.
C.S.B. —— gigas. Belfast Museum.
C.S.B. Ampelisca Belliana. Belfast Museum.
C.S.B. —— typica. Belfast Museum.
C.S.B. Westwoodea cæcula. Belfast Museum.
D. Iphimedia obesa. Belfast Museum.
D. Dexamine spinosa. Belfast Museum.
C.S.B. —— bispinosa. Belfast Museum.
D. Gammarus fluviatilis.
D. —— locusta.
D. —— marinus.
C. —— campylops. Belfast list.
D. —— palmatus. Not in Thompson's list.
C.S.B. —— Othonis. Belfast Museum.
C.S.B. —— gracilis. Belfast Museum.
D. —— longimanus.
C.S.B. Amphitoe rubricata. Belfast Museum.
C.S.B. —— littorina. Belfast Museum.
C.S.B. Podocerus falcatus. Belfast Museum.
C.S.B. Erichthonius ——? Belfast Museum.
D. Corophium longicorne.
D. Hyperia galba. In Acalephæ.
D. ——? cyanea. With the last.
D. Caprella acuminifera.
D. Arcturus longicornis.
D. Idotea pelagica.
D. —— tricuspidata.
C. —— emarginata. Belfast Museum.
D. Limnoria terebrans.
D. Asellus aquaticus.
D. Jæra albifrons?
D. Lygia oceanica.
D. Philoscia muscorum.
D. Philougria riparia.
D. Porcellio scaber.
D. —— pictus.
D. —— lævis.
D. Oniscus murarius.
D. —— fossor.
D. Armadillium vulgare.
C. Anceus maxillaris.
D. Sphæroma serratum.
D. —— rugicauda.
D. Nesæa bidentata.
C. Æga bicarinata. Belfast Museum.

Description of new species of *Crangon*, *C. Pattersonii*, in foregoing list:—Rostrum rounded, apex scarcely length of ocular peduncles; carapace with four (?) lines of spines; abdomen *smooth*, without sulcation, except in telson; in other respects as *Crangon spinosus*.

Additional List of Polyzoa. By the Rev. THOMAS HINCKS.

Crisia eburnea.
Tubulipora patina.
—— incurvata (n. sp.), Hincks.
Diastopora obelia.
Alecto granulata.
—— major.
—— dichotoma-Lamouroux. A single specimen of an Alecto has occurred, which seems identical with the fossil form described and figured by Lamouroux in his 'Exposition Méthodique' under the above name.
Crisidia cornuta.
Salicornaria farciminoides.
Scrupellaria scruposa.
Ætea anguina.
Gemellaria loricata.
Bugula flabellata.
Flustra truncata.
Membranipora pilosa.
—— Pouilletii (Audouin).
—— spinifera (Alder's Catalogue).
—— solidula (n. sp.), Alder MS. Mr. Alder has previously obtained it from other localities.
Membranipora simplex (n. sp.), Hincks.
Lepralia Londsborovii. A very distinct and beautiful form is not uncommon amongst the dredgings, which I refer doubtfully to this species, of which very little is known.
—— concinna.
—— variolosa.
—— nitida.
—— Woodiana (n. sp.), Busk. This fine species has only been known hitherto as a Crag fossil. It will be described and figured by Mr. Busk in his forthcoming Monograph on the Polyzoa of the Crag.
—— Peachii.
—— ventricosa.
—— eximia (n. sp.), Hincks.
Cellepora armata (n. sp.), Hincks. I had already obtained this new species from the Dogger Bank.
Eschara cervicornis, Busk.
Arenella dilatata, Hincks.

I have also met with the Asteroid Zoophyte, *Sarcodictyon catenata* of Forbes.

Appendix to Mr. VIGNOLES' *paper "On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains"* (*Rept. Brit. Assoc.* 1857).

FOR calculations relating to Suspension Bridges, reduced to the simplest terms, and considering the curve of the chain as a parabola:—

Unit of length	1 foot.
„ superficies	1 square foot.
„ volume	1 cubic foot.
„ weight	1 ton.

x=half chord of parabolic curve of chain .
y=versed sine of ditto . . . .
h=semi-parameter of the parabola . . . .
} clear of supports.

N.B. $h=\frac{x^2}{2y}$ by the properties of the parabola.

ω=minimum sectional area of the chain, exclusive of appendages.
n=appendages of the chain. (See explanations, *a*.)
$\omega+n$=sectional area of chain, for calculating its weight and tension.
u=weight of a cubic foot of iron.
e=maximum weight admitted on chain. (See explanations, *b*.)

sec ϕ=length of chain at top or highest part.
sec ϕ'=ditto at bottom or lower part.
k=load on the chain. (See explanations, *c.*)
l=weight of the chain and its appendages.
$k+l=p$=total maximum load on chain for calculating tension.

} corresponding to 1 foot in length, measured horizontally along the chord of the parabolic curve of the chain.

T=tension at any part of the chain.
r=height or depth of abutment.
P=half length of abutment.
W=theoretical weight of abutment to resist tension.

} (See explanations, *d.*)

FORMULÆ.

$$\omega=\frac{k\times\sqrt{h^2+x^2}}{\epsilon-u.n.\sec\phi\sqrt{h^2+x^2}}$$ for sectional area of chain.

$$T=p\sqrt{h^2+x^2}$$ . . . for tension of chain.

$$W=\frac{Tr}{P}$$ . . . . . . for resistance to tension.

a. Appendages of the Chains.—The minimum sectional area of the chains is the product of the breadth and thickness of the iron thereof in its smallest dimensions. But the links of plate-chains overlap each other at their extremities, which are enlarged and connected together by screw-ended short bolts of large diameter, secured by nuts and keys; these additions to the simple chains constitute their appendages, and increase the weight (and *consequently* the *average* sectional area) by about from 20 to 25 per cent. of the *minimum* area. Where wire is employed for the suspension in the form of cables, the appendages thereof will bear a very much smaller proportion than the above to the minimum area, as they consist merely of the wrappings around the steel strands of the cables.

b. Maximum Weight admitted on the Chains.—The *maximum* weight or *strain* on the chains or wire cables of suspension bridges, should not exceed a fourth or a fifth of the *breaking* weight or strain, nor should it exceed materially the half of that strain which would produce a permanent effect upon the natural elasticity of the iron. The breaking weight or strain of good wrought iron varies from 20 lbs. to as much as 28 lbs. (avoirdupois) upon the square inch of the section of the bar. The strain which causes wrought iron to take a *permanent set* (that is, which so stretches the fibres of the iron that their elasticity is injured, whereby the iron no longer returns to its normal length when the strain is taken off), varies from 10 lbs. to 14 lbs. per square inch. Consequently the expression (ϵ) in the formula ought not to be taken higher than from 5 lbs. to 7 lbs., or from 0·0022 ton to 0·0032 ton.

c. Load on the Chain.—This quantity comprises the weight of the suspension rods (dependent from the chains or cables, and from which the platform of the bridge is *suspended*), also the weight of the roadway or platform, and the greatest weight with which the platform can be loaded. These, together, constitute the *load on the chains*, exclusive only of the weight of these chains themselves and of their appendages.

d. Dimensions of the Abutment.—The height or depth of the abutment is to be measured from the point on the outer face thereof, at which the chains enter therein; and the length of the abutment is to be measured from that same point to the point at the opposite or inner side of the abutment to which the chains extend, and where they are attached or fastened by means of mooring-plates, abutting against this extreme end. The weight of the abutment will be calculated from its dimensions, in proportion to the specific gravity of the material employed in its construction; and the actual weight of the abutment, as built, should be from four to five times the theoretical weight, determined by the formula, as that required to resist the tension, exclusive of friction or surface-resistance. If the abutment should be subjected to be surrounded by water, either constantly or periodically, the consequent augmentation necessary in the dimensions and weight of the abutment must be determined, in proportion to the depth of water in which it may be submerged.

Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories.

At the Meeting of the British Association, which was held at Dublin in August 1857, a resolution was adopted, proposing the continuance of the system of magnetical observations which was commenced under the auspices of the Royal Society and of the British Association in 1840; and a Committee, consisting of the President of the Association, the Rev. Dr. Robinson, and Major-General Sabine, was appointed, to request the cooperation of the President and Council of the Royal Society in the endeavour to attain this object, and to take, in conjunction with them, such steps as may appear desirable for that end.

The Committee thus appointed accordingly held a meeting in London, on the 5th November last, at which it was agreed to recommend that hourly observations, for not more than five years, should be undertaken at certain stations in the British Colonies; and a letter was addressed to the President of the Royal Society, asking for his cooperation, and that of the Council of the Society, in endeavouring to attain that object.

This application was favourably received by the Council of the Royal Society; and on the 10th of December, 1857, the following resolution was adopted in reference to it:—

"That Sir John Herschel, the Astronomer Royal, the Dean of Ely, and Dr. Whewell, be appointed a Committee, to cooperate with the Committee appointed with this view by the British Association, and to take, in conjunction with them, such steps as may be necessary, including, if it be thought desirable, an application to the Government."

In consequence of this resolution, a correspondence took place among the members of the two Committees, which having resulted, it is believed, in a general agreement as to the course to be adopted, the joint Committee so acting in cooperation met at Leeds on the 24th September, and in the first instance proceeded to inquire into the nature and scientific value of the results which have already been secured by the system of observation hitherto carried out, at the observatories maintained by the Government, at the joint recommendation of these two bodies; with a view to forming a distinct opinion whether they are such as to merit being regarded as a reasonable, and, what may be called, a remunerative return for the labour and thought bestowed upon them, and the very considerable expenditure of the public money incurred by them. In so doing, they have limited their views to the results, as compared with the expenditure, in the British Colonial magnetic observatories only, without taking into consideration those deducible from observations made under foreign auspices; and they find that, at the cost of an expenditure which may be reckoned at about £400 per annum (exclusive of the cost of instruments, outfit, and publication), for each of the several observatories at St. Helena, Toronto, Hobarton, and the Cape of Good Hope during the respective continuance of each, the accumulated observations, so far as they have yet been discussed, have produced the following results, which they consider as satisfactorily established by the discussion:—

In the first place, the mean state of the several magnetic elements for each of the stations, as reduced to a fixed epoch, has been obtained with a precision of which nothing previously done has afforded any example—emulating, in this respect, the exactness of astronomical determinations, and competent to serve as a fixed point of departure, to the latest ages; and this for each of the elements in question—the dip, the declination, and the intensity of the magnetic force.

Secondly, that at each station, the rate of regularly progressive secular change in all the three elements above-mentioned has been ascertained with a degree of precision which contrasts strongly with the loose and inaccurate determinations of former times.

Thirdly, that the laws of the diurnal, annual, and other periodic fluctuations in the values of these elements, as exhibited at each station, have been established in a manner and with a decision to which nothing hitherto executed in any branch of science, astronomy excepted, is comparable; and that the results embodied in the examination of these laws have laid open a view of magnetic action so singular, and so utterly unexpected, as to amount to the creation of a new department of science, and the detection of a completely novel system of physical relations: for that, in the first place, the systems of diurnal and annual magnetic changes have each been separated into two perfectly distinct and physically independent systems,—the one, at any particular station, holding its course according to laws depending solely on the sun's hour-angle at the moment of observation, and his meridian altitude at different seasons; the other comprehending all those movements which, under the name of magnetic storms, or "irregular disturbances," have hitherto presented the perplexing aspect of phenomena purely casual, capricious in amount and in the particular occasions of their occurrence when regarded singly, has been shown, by these discussions, to be subject in its totality to laws equally definite with the others, though more dependent for their application on peculiarities of local situation. As regards the first of these systems of fluctuation, they find it demonstrated:—

That the sun's regular action on the magnetism of the globe is determined by a law of no small complexity and intricacy, but which, nevertheless, has been traced with precision and certainty, and shown to be referable, in the first place, and for one of its arbitrary coefficients, to the geographical situation of the place of observation with respect to a certain line or equator on the earth's surface, which cannot yet be precisely traced for want of sufficiently numerous stations (but which seems to approach to the line of least intensity and is very far from coinciding with the geographical equator), —and in the next, and for its other influential cause, to the fact of the sun's having north or south declination; so that the whole diurnal change in any one of the elements, and at any station, is made up of two portions, one of which retains the same sign, and a constant coefficient all the year round; the other changes sign, and varies in the value of its coefficient with the annual movement of the sun from one side of the equator to the other.

That, consequently, for a station on the magnetic equator (so defined), the *mean* amount of diurnal change is *nil*, when taken over the whole year; but that on any particular day in the year it has a determinate magnitude, which passes through an annual periodicity, with opposite characters in opposite seasons; and that for a station in middle latitudes the mean diurnal fluctuation is not *nil*, but such as during every part of the year to exhibit an easterly deviation in the morning hours, and a westerly in the evening hours, for stations north of the magnetic equator, and *vice versa* for those south of it; but that the amount of this deviation, or the amplitude of the diurnal fluctuation, varies with the seasons, being exaggerated or partially counteracted by the alternate conspiring and opposing influence of the sun's declination during the summer and winter seasons.

As regards the irregular disturbances, though arbitrary and capricious in extent and in the moments when they may be expected individually, this does not prevent their obeying with great fidelity the law of averages when grouped in masses and treated separately from those of the former class. So handled, they are found to conform in the average effect, at each of the twenty-four hours of the day, and on each day of the year, to the very same rules as regards the sun's daily and annual movement,—with one remarkable point of difference: viz., that their hours of maxima and minima are not identical with those of the regular class, but that each particular station has, in this respect, its own peculiar hours, analogous to what is called the "establishment" of a port in the theory of the tides; and that, in consequence, the superposition of these two systems of diurnal fluctuation gives rise to a series of compound variations analogous to the superposition of two undulations having the same period but different amplitudes and different epochal times, and that, by attending to this principle, many of the most complex phænomena, such as that of a double maximum and minimum, with the occurrence of a nightly as well as a daily movement, are explained in a satisfactory manner.

The discussion of the observations already accumulated has further brought into view, and in the opinion of your Committee fully established, the existence of a very extraordinary periodicity in the extent of fluctuation of all the magnetic elements, and in the amplitude and frequency of their irregular movements especially, which connects them directly with the physical constitution of the sun, and with the periodical greater or less prevalence of spots on its surface,—the maxima of the amount of fluctuation corresponding to the maxima of the spots, and these, again, with those of the exhibitions of the Aurora Borealis, which appears also to be subject to the same law of periodicity—a law which, as it does not agree with any of the otherwise known solar, lunar, or planetary periods, may be considered as, so to speak, personal to the sun itself. And thus we find ourselves landed in a system of cosmical relations, in which both the sun and the earth, and probably the whole planetary system, are implicated.

That the sun acts in influencing the earth's magnetism in some other manner than by its heat, seems to be rendered very probable by several features of this inquiry; and the idea of a direct magnetic influence ext to the earth is corroborated by the discovery of a minute fluctuation in the magnetic elements, having for its period not the solar but the lunar day, and therefore directly traceable to the action of the moon. The detection of this fluctuation by Mr. Kreil, from a discussion of the Prague observations, has been confirmed by the evidence afforded by those of our Colonial observatories, and appears to be placed beyond all question by the recent deductions for the horizontal force and the declination, extending over three years of observation at the Cape of Good Hope, which General Sabine has submitted for your Committee's inspection, and in both which the fluctuations in question emerge in a very satisfactory manner, and one calculated to give a high idea of the precision of which such determinations are susceptible, when it is considered that the total amplitude of oscillation due to this cause in the direction of the Cape-needle is only about 18″ of angle.

Your Committee, looking at this long catalogue of distinct and positive conclusions already obtained, feel themselves fully borne out in considering that the operation in a scientific point of view has proved so far eminently remunerative and successful, and that its results have fully equalled in importance and value, as real accessions to our knowledge, any anticipations which could reasonably have been formed at the commencement of the inquiry.

Having satisfied themselves of the great and important value of the results already obtained, independent of the dormant interest as respects future discussion which the mass of observations accumulated continues to possess, and which it remains for future theoretical combinations to elicit, your Committee next turned their attention to the question whether, and to what extent, the maintenance of some or all of the old Colonial observatories, or the establishment of new ones for a limited term, might be expected, first, to give additional certainty and precision to the determinations already obtained, and secondly to elucidate points imperfectly made out, and more especially geographical relations which determine the greater or less amount of discordance between the epochal hours of the regular and irregular diurnal changes—relations which, no doubt, involve the causes of the irregular fluctuations themselves (causes at present involved in the greatest obscurity)—and to obtain indications of the points in the earth's surface at which the forces producing them originate.

As regards the general question as to the desirableness of some continuation of the observations, its seems hardly to be referred to our consideration as a Committee,—the resolutions come to both by the British Association and by the Council of the Royal Society, in the appointment of their respective Committees of co-operation, indicating an opinion already conclusively formed on the part of both bodies to that effect. They have felt it due to themselves, however, to come to an independent conclusion on that point; and having done so with perfect unanimity, on the grounds already adduced and the expectations for the future which those grounds justify, they next address themselves to the consideration of the two points above indicated, and to the important questions, first, whether to recommend the continuance or resumption of the establishments at the former stations, or the selection of new ones; and secondly, with how few new or revived establishments, with how limited a scale as to extent and expense, and with how short a period as the minimum term of their duration, the expectation of these advantages being secured could be compatible; and finally to fix upon the stations most desirable.

As regards the first point referred to, viz. the more complete establishment of the laws themselves, and the giving of greater numerical precision to their expression, the Committee is of opinion that the laws themselves are not likely to be subverted or contradicted by a larger series of observations at any station for which they have once been shown to prevail; but that every new station differing much in geographical situation from the former in which they might be found verified with or without supplementary modifications, would undoubtedly add strength to the induction by which they have been concluded. Additional numerical precision, on the other hand, would only be attained by a continuance of observations at former stations, and is not a point of sufficient importance, in their opinion, to be entitled to any weight in opposition to considerations in favour of change,—while in the one important case in which such additional precision is especially desirable, that of the solar period, such additional precision will be acquired ultimately as a matter of course by continued observation at any one of the existing permanent observatories, of whose business magnetic observation forms a part, as well as by any amount of Colonial establishments.

It is therefore mainly in the elucidation of obscure and difficult physical points, and in the probable extension of our knowledge of the geographical and other conditions on which the irregular disturbances depend, that our hope of advantage from further observation consists,—our conviction being that, without special observations at well-selected stations (selected, that is, with a view to these objects), there is little or no prospect of further progress. The *general character* of the magnetic phenomena may be considered as secured from loss; but the great problem remains unresolved; the local influences are yet to trace; and the only means of tracing them must consist in varying the position of our stations so as to embrace great differences in geographical situation, and in conformity with such indications as can be gathered from our present experience. The magnetic establishments permanently existing in Europe and America are confessedly inadequate to afford the requisite information. The stations which have occurred to your Committee as most eligible would be Vancouver Island, Newfoundland, the Falkland Isles, Bermuda, Ceylon, Shanghai or some locality in China, and Mauritius; but they are fully aware that to demand from the national purse the institution of observations at all these points, would be more than is warranted by any pressing necessity, and ought therefore not to be insisted on. Among them, the principal in point of interest (for reasons which will be presently mentioned) are Vancouver Island, Newfoundland, the Falkland Isles, and Pekin or some near adjacent Chinese station, such as Shanghai; and the Committee consider that much valuable information would accrue from observations sufficiently prolonged at these, to which, therefore, they would be understood to limit their recommendation. In regard to the length of time over which they would desire to see the observations extended, they consider five years (being about half the solar period, and being also sufficient to give a fair grasp of the secular change of the magnetic elements) as a period both in consonance with that which has been accorded on former occasions, and in some sort designated by the nature of the case.

The reasons which induce them to give a preference to these over the rest of the stations enumerated are as follows:—Between Toronto and Point Barrow the difference of the epochal hours of the irregular diurnal fluctuations is such as to amount to a complete opposition of phases,—a circumstance which goes far to point out the latter station as being in the immediate neighbourhood of the origin of those irregular disturbances. Should observations be established at the two stations now proposed, there is every reason to hope, as will appear from a document drawn up at the request of the Committee by General Sabine, and with his permission appended to this Report, that the observations at Toronto, which have been partially re-established since 1855, would, with a view to cooperation for this especial purpose, be wholly resumed on a fitting application to the Colonial legislature. And in addition to this, should an application made to the Norwegian Government for the establishment, during the same period, of an observatory at the North Cape prove successful (which there is every reason to hope, such an application made on a former occasion having been well received and having ultimately failed owing only to a want of attention to some point of diplomatic form in its mode of communication), we should then have a chain of stations in high northern latitudes, the results obtained at which, being severally brought into comparison with those already procured at Point Barrow, and with each other, could hardly fail of bringing out some very positive conclusion.

As regards the proposal for a station at the Falkland Isles, it is presumed, from the general course of the magnetic line of minimum intensity, that this station will prove, in analogy to the Cape of Good Hope, and in contrast with the northern stations recommended, to have the character of an equatorial, or approximate equatorial station ; and in respect to that proposed in China, that it will complete and carry round the globe the chain of northern middle-latitude stations,—the intermediate links being supplied by the Russian observatories, and by those which it is hoped may be established at the North Cape and at Vancouver Island. As regards the Falkland Isles and Newfoundland, it should be noticed that there exist considerable facilities and conveniences for the comfortable establishment of an observatory there; and in respect of the other two, it may be remarked that they are both points of great present interest, and that a determination of the meteorological as well as magnetic peculiarities of both would be important. The affections of a telegraphic wire by electric discharges in the nature of Aurora Borealis have already attracted attention, and produced confusion in the ordinary use of such wires, and constitute one of the motives for inquiry into the nature and laws of the so-called magnetic storms. It may also be observed that, in reference to the anomalistic equation of the sun's magnetic intensity, or the effect of its annual approach and recess due to the ellipticity of the earth's orbit, the influence of local temperature upon the observations requires to be eliminated, in order to bring this effect into evidence, by a combination of the results obtained at stations whose seasons are opposite.

In reference to the important consideration of keeping down as much as possible the outlay consequent on the establishment of these observatories, your Committee have given attention to the question whether it be desirable to continue, as heretofore, the printing of the observations *in extenso*—a measure resulting in the production of vast and costly volumes, and entailing a great amount of laborious superintendence. They consider that, the form of the observations remaining unaltered, and the principles of their reduction being now rendered familiar, this would not be necessary, provided the original observations were registered in triplicate, and the copies separately deposited in different and secure custody for preservation and occasional reference when required, and provided that sufficient and well-digested abstracts of their reduced results were published. One series of observations, however, they consider must be excepted from this alteration of system:—those of a continuous nature, made on term days, FOUR of which per annum they desire to see still kept up; and those taken on occasions of magnetic storms, when continuous observation is substituted for that on the regular hourly intervals: for the treatment of such observations is still a matter of scientific inquiry; and to render them available in comparison with others, the complete register is indispensable.

Your Committee cannot but contemplate a revival of active interest and cooperative participation in the system of observation, on the part of our Colonial and of Foreign Governments, when once it shall become known that the subject is resumed by our own Home Government in the manner recommended. On this subject they beg to refer to Gen. Sabine's reply to their inquiries, already alluded to, which places in a distinct point of view the expectations which may justly be indulged on that score. In reference, moreover, to the personal and material establishment at each of the Government observatories, this document contains a summary of what is needed, and of what ought to be applied for.

And this leads your Committee to a point which they consider of such importance to the success of the whole proceeding, that they cannot help embodying their opinion on it in this Report. It is of little avail to accumulate observations unless their effective and complete reduction be provided for, and the assurance obtained that when reduced they will undergo such discussion and scientific treatment as shall elicit from them the laws of the phenomena of which they are the records. The zeal and ability with which the present Superintendent of the Government Magnetic and Meteorological Observatories has hitherto executed this task, if extended to the new series now called for, would afford that assurance in its fullest extent; and they earnestly trust that this will not be lost sight of in the arrangements to be made in carrying out their proposals, if adopted.

There is another point to which your Committee consider their attention ought to be paid simultaneously with the establishment of the proposed observatories:—it is that of the extension of Magnetic Surveys of the districts in their immediate neighbourhood, with a view to fixing the situation and direction of the iso-magnetic curves within some considerable adjoining area (in the case of the Falkland Isles, that of the whole group).

On this point the following remarks by General Sabine, in a communication addressed by him to us in reply to certain inquiries which we considered it right to make of him, are, in the opinion of your Committee, conclusive in deciding them to recommend that provision be also made for the execution of such surveys, collaterally with the observations at the fixed stations.

"Recent observations in North America, discussed in the proceedings of the Royal Society for January 7th, 1858, have made known that the general movement of translation of the isoclinal and isogonic lines, which from the earliest observations have been progressing from West to East, has within a few years reached its extreme eastern oscillation, and that the movement in the reverse direction has already commenced; we live therefore at an epoch in the history of terrestrial magnetism which we have reason to believe will be regarded hereafter—when theory shall have more advanced—as a highly important and critical epoch. The geographical position of the maximum force in the Northern Hemisphere appears to have reached its extreme easterly elongation, and from this time forth may be expected to move for many years to come towards the meridian which it occupied in Halley's time, accompanied by a corresponding change in the positions and forms of the isodynamic, isoclinal, and isogonic lines in North America; a careful determination of the absolute values and present secular change of the three elements at this critical theoretical epoch, at stations situated at either side of the American continent, and nearly in the geographical latitude of the maximum of the force, would furnish therefore data for posterity, of the value of which we may have a very inadequate appreciation at present. I may refer to the discussion prefixed to the third volume of the Toronto Observations, to show that the means and methods with which we are conversant are adequate for the purpose, and I may indicate Vancouver Island and Newfoundland as colonies well suited for establishments of the same nature as those of which the efficiency has been proved."

As regards the instrumental means to be employed, the Committee believe that the consideration of the subject would be more fitly undertaken by the Royal Society, who will probably think it right to appoint a special committee, as was done on the former occasion, to consider it maturely, and to report upon it. Well as, in general, the instruments employed in the British colonial observatories have performed, it may be desirable to consider whether they could not be improved, by diminishing considerably the size of the magnetic bars employed. Small bars indicate more certainly the rapid magnetic changes; they may be hardened more perfectly, and therefore vary less in their magnetic condition with changes of temperature; they admit of more perfect protection from the effects of disturbing aërial currents; and finally, the instruments may be constructed at less expense, and may be grouped together in a smaller and less costly building.

The joint committee therefore have finally agreed to the following resolutions, which they submit for approval to their respective appointing bodies:—

1. That it is highly desirable that a series of magnetical and meteorological observations, on the same plan as those which have been already carried on in the colonial observatories for that purpose, under the direction of H.M. Board of Ordnance, be obtained, to extend over a period of not more than five years, at the following stations:—

1. Vancouver Island.
2. Newfoundland.
3. The Falkland Isles.
4. Pekin, or some near adjacent station.

2. That an application be made to her Majesty's Government, to obtain the establishment of observatories at these stations for the above-mentioned term, on a personal and material footing, and under the same superintendence, as in the observatories (now discontinued) at Toronto, St. Helena, and Van Diemen Island.

3. That the observations at the observatories now recommended should be comparable with and in continuation of those made at the last-named observatories, including four days of term-observations annually.

4. That provision be also requested at the hands of Her Majesty's Government, for the execution, within the period embraced by the observations, of magnetic surveys in the districts immediately adjacent to those stations—viz. of the whole of Vancouver Island and the shores of the strait separating it from the main land, of the Falkland Isles, and of the immediate neighbourhood of the Chinese observatory (if practicable) wherever situated—on the plan of the surveys already executed in the British possessions in North America and in the Indian Archipelago.

5. That a sum of £350 per annum, during the continuance of the observations, be placed by Government at the disposal of the General Superintendent, for the purpose of procuring a special and scientific verification and exact correspondence of the magnetical and meteorological instruments, both of those which shall be furnished to the several observatories and of those which, during the continuance of the observations for the period in question, shall be brought into comparison with them either at Foreign or Colonial stations.

6. That the printing of the observations *in extenso* be discontinued, but that provision be made for their printing in abstract, with discussion, but that the term-observations, and those to be made on the occurrence of magnetic storms, be still printed *in extenso*; and that the registry of the observations be made in triplicate—one copy to be preserved in the office of the General Superintendent, one to be presented to the Royal Society, and one to the Royal Observatory at Greenwich, for conservation and future reference.

7. That measures be adopted for taking advantage of whatever disposition may exist ont he part of our Colonial Governments to establish observatories

of the same kind, or otherwise to co-operate with the proposed system of observation.

8. That in placing these resolutions and the report of the Committee before the President and Council of the Royal Society, the continued co-operation of that Society be requested in whatever ulterior measures may be requisite.

9. That the President of the British Association be requested to act in conjunction with the President of the Royal Society, and with the members of the two Committees, in any steps which may appear necessary for the accomplishment of the objects above stated.

10. That an early communication be made of this procedure to His Royal Highness the Prince Consort, the President elect of the British Association for the ensuing year.

Appendix.

Letter from General Sabine to Sir John Herschel.

St. Leonard's, June 26th, 1858.

My dear Sir,

You wish me to state for the consideration of the Committee what *specific* measures for the continuance and extension of magnetical researches appear to me suitable to the present state of that branch of science, and at the same time sufficiently moderate and reasonable to justify the expectation that the portion of them which requires it may receive the sanction of Her Majesty's Government.

For this purpose it may be convenient to divide the subject generally under three heads, and to consider separately what may be expected,

1st. From our own Government;
2nd. From our own Colonies;
3rd. From foreign Countries.

1st. *From our own Government.*

The establishment, for a limited period, of Observatories in the three colonies,

Vancouver Island,
Newfoundland,
The Falkland Islands,

on a similar plan to those which were established at Toronto, St. Helena, and Hobarton, and which have now ceased, having accomplished their objects. The "personnel" at each of these three observatories to consist of an officer, four non-commissioned officers, and one private, either of the Artillery or of the Engineers, with the same extra pay and allowance for incidentals as was the case in the observatories which have terminated. The instruments, both absolute and differential, to be of the same description as before, with of course such modifications and improvements as experience has suggested. The instruments to be prepared at Kew, and the directors of the three observatories to be instructed there. The system of observation to be hourly, Sundays, Christmas-days, and Good Fridays excepted. The time to be employed to be mean astronomical time at the station, both for magnetism and meteorology. The observatories to be maintained until five complete years of observation are obtained. The number of term-days in each year to be reduced from twelve to four.

The public departments whose sanction will be required are, the Treasury for the expense, and the General Commanding in Chief for the selection and appointment of the officers and non-commissioned officers. In addition to the officer for each observatory, a fourth officer will be required as an assistant to the general Superintendent, in carrying on, under his direction, the details of correspondence with the observatories. Total, four officers, twelve non-commissioned officers, and three privates.

2nd. *With reference to our own Colonies.*

As soon as the sanction of Government has been obtained for the observatories already named, the governors of British Guiana, Mauritius, and Melbourne may be written to, suggesting that a communication should be addressed from each of those colonies to the Secretary of State for the Colonies, expressing the desire which is felt in the colony to participate in the proposed systematic researches, stating what facilities can be afforded, and what portion of the expense can be borne by the colony itself, and requesting to be placed in official communication with some suitable authority for the preparation of instruments, and for furnishing such instruction and advice as may be required.

The accompanying letter from Lieutenant-Governor Walker, of British Guiana, to Mr. Sandeman (which has been just forwarded to me), will show how ready that colony is to take its part, and that it waits only for that measure of countenance and encouragement which it reasonably expects, and ought to receive, from the mother country. At Mauritius, a Meteorological Society formed by the colonists themselves is most actively and usefully employed in tracing out, by means of the logs of merchant vessels, the phænomena of the storms by which navigation in that vicinity is troubled, and is making most pressing appeals for an authorization which should enable them to add researches in magnetism to those in meteorology,—having on the spot, in Captain Fyers of the Royal Engineers, a person who would make an admirable director of such an establishment. At Melbourne, a proposition for a magnetic observatory and survey is now before the local government; means are abundant, but instruments and direction are wanting. Mr. Jeffery, so well trained in the Hobarton observatory, is in that country, and is desirous of such employment, as M. Neumayer is of being engaged in the survey. Melbourne would be a most important station for a magnetic observatory, as we might expect from it the verification or otherwise of the increase in the magnetism of the earth, at the period of the year when she makes her nearest approach to the sun.

Other Colonies might follow the example; but in regard to these three we are justified in expecting that, with suitable measures of encouragement, we should have thoroughly efficient establishments, carrying out the system of observation in its completeness.

3rd. *With reference to foreign countries.*

A proposition has recently been made to the Netherlands' Government, by Dr. Buys Ballot (who fills the same official position in Holland that Admiral FitzRoy does in this country), for the establishment of a magnetic observatory in the Dutch Colony of Batavia; and Dr. Buys Ballot has written to inquire whether, in the event of the proposition being acceded to, two sets of instruments, one for Batavia and the other for Utrecht, could be prepared at Kew. An intimation that the British Government was about to resume and extend its magnetical researches might be expected to have a favourable influence on the success of Dr. Buys Ballot's proposition, and might also lead to the adoption of our colonial system of observation in its full extent at the Batavian observatory.

The importance of the North Cape of Europe as a magnetical station, especially with reference to the connexion between the Aurora and the magnetic disturbances, has already been noticed in a preceding letter from me (that of May 13). The instruments which were prepared some years ago at the expense of the Royal Society, and were intended to be presented to the observatory at the North Cape (should one be established there by the Norwegian Government), are still in existence, and with a few modifications might be applied to their original purpose. The re-establishment of magnetic observatories in the British Colonies might furnish a favourable occasion for reviving, in concert with M. Hansteen, a proposition for an observatory at the North Cape, which seems to have failed on the former occasion rather from an accident than from any real difficulty in the matter itself.

M. Secchi, of the Observatory of the Collegio Romano, at Rome, has recently been supplied from Kew, at the expense of the Papal Government, with a complete equipment of magnetical instruments, similar to those which have done such good work in the British Colonial establishments. With the encouragement derived from the revival of active measures here, M. Secchi might hope to obtain the aid which he desires, in the way of temporary assistance, to enable him to carry out the complete system of observation for which he is already provided with the instrumental means.

The concert which has prevailed between Russia and England in magnetic operations gives reason to hope that renewed activity here might so far strengthen M. Kupffer's hands as to enable him to carry out efficiently the hourly system of the three elements, at one at least of the stations in Eastern Siberia, the probable importance of which can scarcely be overrated.

A meteorological observatory has recently been instituted at Havana; and the director, M. Poey, has proposed to the Cuban authorities the purchase of magnetical instruments, to be prepared at Kew, and a sufficient increase of assistants to provide for observations to be made with them. M. Poey is active and intelligent, and has recently visited the principal magnetic institutions in Europe. He would not fail to avail himself of the support which his proposition would derive from the measures which might be taken here.

The Regents of the Smithsonian Institution at Washington have agreed to allot a portion of their funds to a magnetic observatory; but neither the instruments nor the system of observation have yet been determined: their decision might probably be hastened by the knowledge that active measures are in progress here.

Viewing the necessity of resorting to means of securing and ascertaining a precise correspondence between the magnetical and meteorological instruments which may come to be used in these operations, or in cooperation with them in other quarters, as well as their exact and scientific adjustment, as also of securing a self-registered series of photographic delineations of the solar spots during their continuance, it is proposed that, during the continuance of the observatories, an annual sum, not exceeding £350, should be taken on the estimate, and placed at the disposal of the general Superintendent for these purposes.

There is a point referred to in a former letter which will require the attention of the Committee: it is the question whether the observations of the proposed observatories should be printed *in extenso*, or in abstract accompanied by a discussion of the principal results.

I remain,

My dear Sir,

Faithfully yours,

EDWARD SABINE.

Sir John Herschel, Bart.

Description of a Self-recording Anemometer. By R. Beckley, *Assistant at the Kew Observatory of the British Association.*

In all cases in which the system of hemispherical cups (devised by Dr. Robinson as a measurer of the velocity of the wind) has been used, the direction-apparatus has required a distinct support on the exterior of the building. In my arrangement, a cast-iron tubular support (fig. 1, Plate XIX.) carries the whole of the external parts of the instrument, which can be easily adapted to any form of building upon which it is desirable to mount it.

The general arrangement will be better understood by reference to fig. 3, Pl. XIX., showing the same in section.

Upon the wind moving the cups, motion is given to the tubular shaft *a a a*, the lower end of which is provided with an endless screw *q*, that works into the worm-wheel *a*, fig. 1, Pl. XX.: thence motion is communicated to the registering pencil A.

The *fan* or *windmill governor* was first used by Mr. Osler for indicating the direction of the wind, owing to its steadiness compared to a vane. I have therefore adopted it, but use two, D, D, fig. 2, Pl. XIX., fixed directly on to the worm-spindle A, working into the fixed wheel B; by this arrangement a countershaft is dispensed with. The bearings of the worm spindle A run upon four rollers, *n*, *n*, *n*, *n*, fig. 3, Pl. XIX., contained in the boxes *c*, *c*, fig. 2, Pl. XIX. A section of the box and rollers is shown at fig. 4, Pl. XIX.

The action of the fans is to keep their axis at right angles to the direction of the wind; any change taking place, they right themselves, carrying with them the outer brass tube *b b*, fig. 3, Pl. XIX., which is screwed to a long tubular fitting of cast iron, *e e*, the top of which is formed to receive the friction-balls *t*, *t*, and with a shoulder which bears upon the friction-balls *u*, *u*. To the lower end of this fitting is fastened the necessary length of brass tubing, *g g*, completing the direction-shaft, on the lower end of which is a mitre wheel, *c*, fig 2, Pl. XX.

The method of registration consists in using De la Rue's metallic paper, this paper having the property of receiving a trace from a brass pencil. Pencils can therefore be made of any form desired.

In the first instrument made by Mr. Adie, of 395 Strand, from my drawings, the velocity is registered by motion being given to the segment of teeth A, fig. 4, Pl. XX., taking into two racks, B, B, alternately, each traverse being equal to fifty miles of horizontal movement of the air, the pencil being inserted in the eye C; and the direction of the wind is registered by a spiral, of such a figure that equal angles correspond to equal increments of arc D, fig. 4, Pl. XX., which is in fact a screw upon a plane, on the edge of which is screwed a thin strip of brass, E. This, being kept against the paper by a spring, forms the direction-pencil.

In the instruments recently made, I have placed the strip of brass or pencil round the cylinders A and B, fig. 2, Pl. XX., making a very thin-threaded screw,—the advantages of such an alteration being that the point of contact of two cylinders is less than in the case of a cylinder and a plane, and then requires no spring or appliances to keep them up to their work.

In reference to the figures 1, 2, and 3, Pl. XX.—The worm-wheel *a*, fig. 1, is moved one tooth by each revolution of the hemispherical cups, and is provided with such a number of teeth that one whole turn is equal to one mile of movement of the air. On the same axis is a mitre wheel, *e*, working into its fellow, *e*, fixed on and giving motion to the inclined worm shaft *f*, which works into the worm wheel *g*, having fifty teeth, one whole turn being equal to fifty miles of wind. On the same fitting, and moving with it, is the wheel *i*, working into its fellow *j*, which is fixed on and gives motion to the axis of the screw-pencil cylinder A: these wheels are kept in gear by the radial arms *o*, *o*. The pitch of screw for the velocity-pencil is equal to a scale of fifty miles upon the paper on the cylinder C. By this method I get a very open scale within a small space.

Any change in the direction of the wind is communicated to the mitre wheels *c*, *c*, fig. 2, Pl. XX., fixed to the shaft K, on the other end of which is the wheel *l*; from this, by two others, *m*, *m'*, a corresponding motion is given to the wheel *n*, fixed on the axis of the screw-pencil cylinder B. I found it better to introduce the small wheels *m*, *m*, running on studs in the shifting arm P, for the direction-pencil, as the motion is variable. The pitch of the screw is equal to a scale of the cardinal points of the compass upon the paper.

While these pencils are being acted upon by the wind, the clock gives a uniform motion of ½ in. per hour to the cylinder C, upon which the paper is fastened,—in connexion with which I beg to say that, as the clock must be wound up daily, and as the time occupied in changing the paper is not more than two or three minutes, I think it better to do so than to have a continuous roll of paper lasting many days, which certainly is not so convenient for reference as the daily record of 12 inches by 8 inches.

By using the spiral form of pencil, I overcome the trouble attending the old method, viz. the pencil shifting off the scale. To ensure registration, it is usual to have three scales upon the paper, and set the pencil on the centre; but even then, should the wind shift twice round in one direction, it ceases to indicate: by my method it must at all times register upon the one scale. Fig. 5, Pl. XX., is a copy of a sheet from the Kew Observatory, in which the advantage is evident.

In conclusion, I would suggest that as the pencils are kept upon the paper by their own gravity, requiring no attention and being as long as the trace they make, they will last a long time. The space required for the instrument not being more than 18 inches × 8 inches, I should recommend its being placed upon a bracket as close to the roof of the building as convenient, similar to the anemometer at Kew, it being very advantageous to keep the shaft as short as possible.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

quite destitute of knowledge of their laws and progress; for when an unexpected stranger of this class blazes forth in our sky (as is the case at this moment), as soon as he has shown himself for a few days, we can mark the path which he will follow, the rate at which he will travel, and in a great degree the appearances which he will assume. And even objects which as yet are still more lawless and perplexing to our science than comets are, are still not altogether extraneous to the domain of our knowledge. There is a class of such objects which has been especially attended to by the British Association. This is the subject of the first of the communications which are to be laid before this Section to-day. I speak of Prof. Powell's 'Report on Luminous Meteors.' These objects, falling stars, shooting stars, fiery globes, or whatever they may be commonly called, have attracted the attention of this Association for many years; and the Report which we are to have laid before us to-day is the continuation of several Reports of the same kind prepared by the same gentleman in preceding years. These bodies, as I have said, are in a great degree irreducible to laws and extraneous to our science; yet not wholly so. We have speculations of recent times by some of our most eminent philosophers, in which these bodies play an important part. Prof. W. Thomson has been led, by his mathematical speculations on Heat, to the conclusion, that the heat of the sun is maintained by the perpetual falling in upon his surface of the abnormal bodies moving in the solar system, which appear to us as luminous meteors and shooting-stars. And he conceives that he has shown that there is in those bodies a sufficient supply to keep up the heat of the sun; and that, by the effects of them, the sun may have gone on radiating heat for thousands and thousands of years without the smallest diminution. And this, again, is the result of profound and complex mathematical calculations,—so wide is the domain of mathematical reasoning, and so necessary is it in any line of speculation in which we are to convert our ignorance into knowledge. I may mention, as another example of this, a case which is far removed from the vastness of astronomical phenomena,—a case of the manifestation of mathematical law upon a scale of the smallest dimensions, and in the work of a humble insect. I speak of the form of the cells of bees: a mathematical problem which already attracted the attention of the ancient Greeks, and which has been the subject of mathematical investigation by several of the most eminent mathematicians of modern times;—the most eminent, for being a problem involving the properties of space of three dimensions, it requires considerable powers of mathematical conception. Upon this subject two communications are promised to the present Meeting, to be laid either before this Section or the Section of Natural History. And in order further to exemplify the advantages derived from the action of the British Association, I may mention another report upon a very different subject, Mr. Cayley's 'Report on the Progress of Theoretical Dynamics.' The generality, multiplicity, and complexity of the recent labours of analysts in this department of mathematics have been so great, that ordinary mathematicians cannot hope to follow them by reading the original memoirs; and I am greatly obliged, as one of them, to Mr. Cayley for enabling us compendiously and easily to understand what has been done and how it has been done. Perhaps, after all, his Report is not so very unlike that of Prof. Powell 'On Luminous Meteors;' for the original researches of the great analysts who have treated this subject, though bright and objects of wonder, are so far above our head and so difficult to understand, that they are not unlike the things tabulated in the other Report. And now, having explained that we must often be necessarily difficult to follow in this Section, I must ask the ladies and gentlemen here present, as the *Spectator* asks his readers, to believe that, if at any time we are very dull, we have a design in it.

On a General Method of deriving the Properties of umbilical surfaces of the second order, having three unequal axes, from the properties of the sphere. By the Rev. J. Booth, *LL.D., F.R.S.*

The author called the attention of the Section to the researches of M. Chasles and other French geometers, on the methods of deriving the properties of surfaces of revolution from those of the sphere by the method of "Reciprocal Polars," and called attention to the fact, that they did not grapple with the more general problem when the three axes are unequal. Dr. Booth mentioned as the results of the method he developed, that every umbilical surface of the second order has four directrix planes parallel to the circular sections of the surface; that these directrix planes—when the surface is an ellipsoid—pass two by two through the directrices of the principal section, in which lie the greatest and mean axes; that every such surface has four foci situate two by two on the umbilical diameters; that when the surface is an oblate spheroid, the four directrix planes are reduced to two parallel to the equator; and he concluded by showing that every graphic property of the sphere may be reproduced in an analogous form in umbilical surfaces of the second order having three unequal axes.

On the Mutual Relations of Inverse Curves and Inverse Curved Surfaces. By the Rev. J. Booth, *LL.D., F.R.S.*

Inverse curves and inverse curved surfaces were defined as curves and surfaces, the product of whose coincident radii vectores is constant; he showed that the tangents to the two curves are equally inclined to the common vectors; that the sum of the vectors drawn from the common pole to the two inverse points, each divided by its corresponding cord of curvature drawn through the pole, is constant and equal to unity; that if $u=\frac{1}{r}$, r being the radius vector of the primitive curve, the arc of the derived curve is the same function of u that the arc of the original curve is of r. He showed, also, that the element of the arc of the inverse curve represents the velocity of a planet in its orbit through the corresponding element of its orbit, assumed as the primary curve. He moreover proved that the circle is inverse to a circle, but when the pole is on the circumference the inverse curve is a right line; that when the focus of a parabola is the pole, the inverse curve is a cardioid; but that when the vertex is the pole, the inverse curve is the cissoid; that the spiral of Archimedes is inverse to the hyperbolic spiral, while the logarithmic spiral is inverse to itself. He drew attention also to certain curves which are inverse to themselves, pointed out the facilities which this inverse method affords of passing from curves of the second order to corresponding properties of curves of the higher orders, and concluded by stating that the theory would be fully developed in the forthcoming Numbers of the 'Quarterly Journal of Pure and Applied Mathematics.'

On the Notion of Distance in Analytical Geometry. By A. Cayley, *F.R.S.*

The author remarks that the principles of modern geometry show that any metrical proposition whatever is really based upon a purely descriptive proposition, and that these principles contain in fact a theory of distance; but that such theory has not been disengaged from its applications and stated in a distinct and explicit form. The paper contains an account of the theory in question, viz. it is shown that in any system of geometry of two dimensions, the notion of distance can be arrived at from descriptive principles by means of a conic termed the Absolute, and which in ordinary plane geometry degenerates into a pair of points.

On Dr. Whewell's *Views respecting the Nature and Value of Mathematical Definitions. By* J. Pope Hennessy, *of the Inner Temple.*

Having briefly referred to the several controversies which had taken place on this subject, the author remarked that the question at issue was equally interesting to two great divisions of the scientific world—the mathematical and the metaphysical. That question is, Are the deductions of mathematical reasoning absolute truths, or are they merely hypothetical? Against the form of the reasoning there could be no objection. It was that of the ordinary Sorites, and might, with a little labour, be split up into separate syllogisms. This had, in fact, been done, with some of the books of Euclid, by two foreign mathematicians. The reasoning process then being perfectly sound, the absolute truth of the conclusion must depend on the absolute truth of the first premiss; in other words, it must depend on the nature and value of the definitions. If, as had often been asserted, a mathematical definition was merely an arbitrary phrase employed to prevent useless repetition, it would be valueless as far as the deduction of truth was concerned. An arbitrary definition never could lead to absolute truth. But if the definitions were not merely an assumed form of words, if, as Mr. Hennessy believed, they were necessarily involved in that fundamental conception under which the mind contemplates the foundations of geometry,—the idea of space—then the conclusions would be, in every sense of the word, true. There were two ways in which the necessary truth of the definitions might be shown. The first, and by far the most important, was by a metaphysical analysis. This had been done successfully by Dr. Whewell. The second, which had not hitherto been attempted, was by a careful comparison of the definitions one with another. This Mr. Hennessy then proceeded to do. Taking the earliest examples with which we are acquainted, he showed that Euclid's definition of a right line and his definition of a plane surface had the same differentia. Plato's definitions bore a similar intimate relation to each other. Hero's definition of a plane surface, and that adopted some centuries afterwards, of a right line, were also similar. He pointed out that such analogies may be traced throughout the whole group of definitions, in which not only Euclid's Geometry, but any mathematical work whatever, as the mathematical Euclid, for example, is built up. Where the analogy appears to fail, it will be found, on careful examination, that it only makes the case still stronger. For instance, Euclid's definitions of a circle and of parallel lines appear not to have the slightest analogy. This is readily explained by the fact that the latter definition, as every one admits, is defective. But when we substitute for the defective definition one which is sound and useful, an analogy becomes evident. Parallel lines may properly be defined to be two right lines, the perpendicular distances between which are all equal. A definition closely resembling this had been used by Boscovich and Wolfius. From it every property of parallels may be easily deduced. Euclid's definition of a circle is, a continued line having a certain point within it from which all right lines drawn to the continued line are equal. Now all the radii of the circle are perpendicular to the circumference; and if we could suppose one line, of two parallels, to become a point, the other would become a circle. The close analogy between the definitions of these two important conceptions is thus evident. He believed also that these definitions contained the germs of all the properties subsequently developed. If a definition were not a necessary truth, but were merely an arbitrary form of words employed to prevent repetition, such analogies as these never would have existed. Their existence shows that mathematical definitions are neither accidental nor mere matters of choice.

On some Properties of a Series of the Powers of the same Number. *By* J. Pope Hennessy, *of the Inner Temple.*

The author announced the discovery of some general laws which regulate the series of the powers of any number. For instance, in the following series of the powers of 5, the number of digits in the several recurrent vertical series may be expressed by the powers of 2:—

Number of digits recurring.			
	5	...	1st.
1	25	...	2nd.
2	125	...	3rd.
	625	...	4th.
4	3125	...	5th.
8	15625	...	6th.
	78125	...	7th.
16	390625	...	8th.
32	1953125	...	9th.
	9765625	...	10th.
64	48828125	...	11th.
128	244140625	...	12th.
256	1220703125	...	13th.

—The vertical series are,

5
2
16
3580
17956240
3978175584236200
19840377976181556439582242163600.

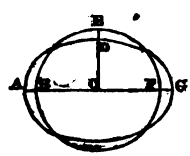
The next consists of 64 figures, and so on. He pointed out that a similar law existed for every other number; and he exhibited formulæ by which the sum of any of the recurrent series may be determined. In the case of 5, $S_n=2\,(S_{n-1}+1)$, the consecutive sums of the several series being 7, 16, 34, 70, 142, &c. In this way tables of the powers of numbers may be constructed to any extent whatever with very little labour. This discovery will enable certain calculations to be made with a degree of accuracy hitherto impossible.

On the Conditions of Equilibrium in a Rotating Spheroid. *By* Dr. F. A. Siljeström, *of Stockholm.*

In the 'Mécanique Céleste' it is demonstrated that, the earth being considered as a fluid mass rotating with a given velocity, the mathematical conditions of equilibrium may be satisfied not only by the spheroid of small excentricity, which is the earth's actual form, but also by another quite flat ellipsoidal figure. The following remarks may in some measure serve to elucidate this very curious result of the calculus, and also show that there really is some difference (and that an important one) between the two states of equilibrium corresponding to the said figures.

Supposing the mass to be in equilibrium with an ellipsoidal figure, the equation of condition (though deduced from much more general principles) implies nothing more than the hydrostatical equilibrium in the centre of the figure between a polar and an equatorial fluid column. If, now, the excentricity is thought variable (the mass being constant), it can be shown that the value of the equatorial pressure (considered as a function of the excentricity) has a *maximum*, on both sides of which there may be a value equal to that of the polar pressure; consequently two states of equilibrium and two different figures.

Considering these two states of equilibrium, it is further shown that if in each case the excentricity is thought a little increased or diminished, the corresponding variations of the polar and the equatorial pressure will follow in such a manner that only with the figure of small excentricity (the earth's actual form) there will be *stability of equilibrium*.

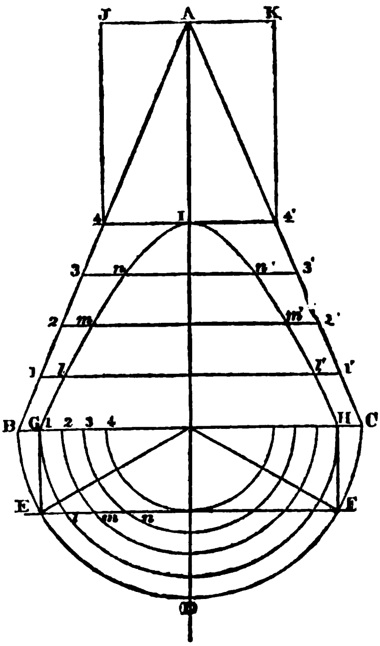


Let EBF represent the actual figure of the earth, and suppose the figure change as DAG. Then the equatorial pressure AC will be > polar pressure DC, and consequently there will be a tendency with the mass to resume the former figure. But if EBF represents the other (elongated) figure of equilibrium, and the excentricity is likewise thought a little increased, then the pressure of AC will prove < pressure of DC, and consequently the mass will have a tendency still more to change in the same direction.

As for Jacobi's famous ellipsoid of three different axes, it will in no way, if examined in this manner, afford stability of equilibrium. Consequently with a given velocity of rotation there can be *only one* ellipsoidal figure with which a fluid mass, subject to its own attractive forces, may remain in a real state of equilibrium.

On a Mode of constructing the Rectangular Hyperbola by Points. *By* G. Thurnell.

This communication was illustrated by two figures. In the first was shown how by means of lines drawn in an isosceles triangle parallel to its base, on which were formed concentric arcs, and through which was drawn, parallel to the base, a sectior line cutting the arcs in two points, from which were projected upon the lines in the triangle other points, these last being the points for the desired hyperbola. See figure.



In the second it was shown how to apply this problem in forming the model by which to work the shafts of columns with hyperbolical entasis, the subject being illustrated by exhibiting the contour of a column of the Parthenon.

On a mode of constructing Tables of Squares and Cubes.
By C. M. WILLICH, *Actuary, University Life Office.*

LIGHT, HEAT.

On Heat and on the Indestructibility of Elementary Bodies.
By Miss ROSINA ZORNLIN. (*Communicated by* S. W. AYRTON.)

On the Duration of Luminous Impressions on certain Points of the Retina.
By Sir DAVID BREWSTER, *K.H., F.R.S. L. & E.*

It is well known that the duration of luminous impressions on the retina is one-third of a second for white light of ordinary intensity. In the Report of the Belfast

Meeting, I have shown that the small circular area at the end of the optical axis, whether it be retina or choroid, retains light longer than the general retina, after the eye has been exposed to light; and I have recently observed that certain points of that membrane, situated apparently near its termination at the ciliary processes, have even a greater retentive power. In order to observe this curious phenomenon, we must extinguish, suddenly, a gas-flame, to the light of which the eye has been for some time exposed. We shall then observe a number of bright luminous points arranged in a circle, the diameter of which is about 72°. These bright points, or stars, apparently placed at equal distances, vanish so quickly that I have found it very difficult to determine their number. They may amount to fifteen or twenty. I have sometimes observed them upon extinguishing a candle, and also upon quickly shutting the eyes. The parts of the retina from which these points of light emanate are probably places where the retina is attached to the ciliary ring, or other parts in the interior of the eye, and may therefore be detected by the anatomist.

On Vision through the Foramen Centrale of the Retina. *By* Sir David Brewster, *K.H., F.R.S. L & E.*

At the Meeting of the British Association which was held at Belfast I gave an account of a case of vision, in which it was performed entirely by the choroid coat, or rather through the foramen centrale of the retina. The space of distinct vision, as ascertained by the number of minute printed letters which the patient could read, was $4\frac{1}{2}$°, the angle subtended by the foramen, which I had previously determined by experiment. In this case the paralysis of the retina was permanent, and the patient was blind, with the exception of the small amount of vision which he enjoyed through the foramen. In the case to which I now call the attention of the Section, paralysis was temporary, and was accompanied with severe headaches; but as soon as the patient recovered her health, the retina resumed its usual functions. In order to find the area of distinct vision, the patient observed with care the number of small and sharply printed letters which she could read at a certain distance from the eye; and upon measuring the breadth of these letters, and their distance from the eye, I found that they subtended an angle of $4\frac{1}{2}$°, corresponding with the size of the opening in the retina. These facts, when viewed in connexion with those which I described at the Swansea Meeting, may throw some light on the functions exercised by the retina as a whole, or by some of its individual layers. I have placed it beyond a doubt, that the membrane, whether choroid or retina, which occupies an area of $4\frac{1}{2}$° at the extremity of the optical axis of the eye, is in certain cases *less retentive* of luminous impression, and in others *more retentive* than the retina. If the microscope proves that there is no retina corresponding to that area, we must consider the choroid coat as the seat of vision. If it should prove that any one of the layers of the retina occupies that area, while the rest are wanting, it will be manifest that that layer is the seat of vision, or rather of luminous impressions.

On certain Abnormal Structures in the Crystalline Lenses of Animals, and in the Human Crystalline. *By* Sir David Brewster, *K.H., F.R.S. L. & E.*

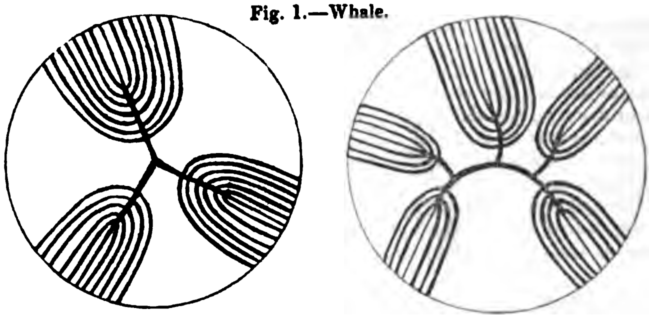
In examining, many years ago, the structure of the crystalline lens in the Mammalia, Birds, Fishes, and Reptiles, the results of which are printed in the 'Philosophical Transactions,' I observed several deviations from the normal structure of particular lenses, which I did not think important enough to publish. Having found, however, that these abnormal structures have been in some instances taken for the true structures, and that structures accurately determined have, on their authority, been considered erroneous, it is necessary to draw the attention of anatomists to the subject.

In the lenses of several large whales brought home by the Arctic navigators, I found that the fibres were related to *four* rectangular septa*; but in one lens I found

* Phil. Trans. 1836. plate 5. figs. 1, 2, No. 4.

only *three* septa on the anterior surface, and *five* on the posterior surface, as shown in fig 1, two of the three septa being doubled at their extremities. Now Leeuwen-

Fig. 1.—Whale.



hoek * found in the lens of a whale *five* septa inclined 72° to each other, which doubtless was an abnormal structure, such as that now described, arising either from disease or old age.

In the lens of the Cow, and generally speaking of most quadrupeds, there are *three* septa inclined 120° to each other ; but in the lens of a cow eleven years old, I found *four* septa on one side of the lens and *seven* on the other, very unsymmetrically disposed. In the other lens of the same cow there were *six* septa on each side, also unsymmetrically disposed. In both these cases the additional septa are placed at the extremities of the *three* normal septa. These structures are exhibited in figures 2 and 3.

Fig. 2.—Cow.

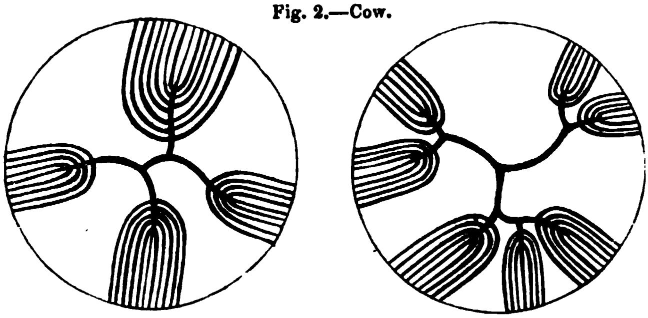
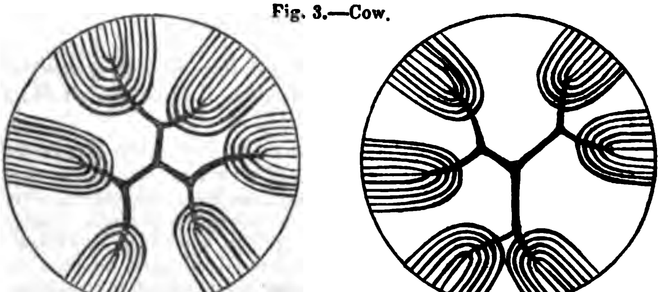


Fig. 3.—Cow.

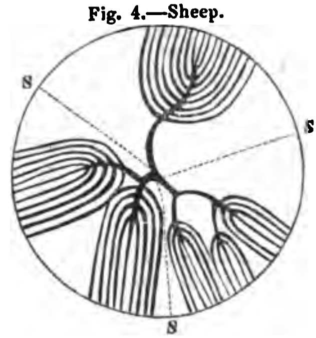


In a Cheviot ewe six years old, both its lenses had *three* perfectly regular septa in their *anterior* surface. In one of them the only irregularity in the *posterior* surface

* Opera, tom. ii. p. 66. Lugd. Batav. 1722. Phil. Trans. vol. xxiv. 1704. No. 23. p. 1723.

was that the septa were not straight lines, and not inclined to each other at angles of 120°; but in the posterior surface of the other there were *six* septa, placed so unsymmetrically, as in fig. 4, that *five* of them were in one semicircle, while only *one* was in the other.

Fig. 4.—Sheep.



When the lenses now described were immersed in distilled water and examined by polarized light, the optical figures which they exhibited were not in the slightest degree disturbed by the want of symmetry in the number and position of their septa.

It will be seen from the figures, that in numbering the septa I have counted only those from which the groups of fibres, or *vortices* as they have been called by Leeuwenhoek, take their origin.

If the abnormal structures now described are the result of disease, or of that change in the lens which is produced by age, it is very probable that several of the varieties of structure observed in the human crystalline are *abnormal*. Reil * thought he saw in a human fœtus, seven months old, *six* septa radiating from each pole, while in adults there were only *four*. Dr. Thomas Young † has given a drawing of the human crystalline (fig. 93) in which the fibres occupy *ten* groups or vortices, separated by *ten* radial lines extending from the margin to the centre of the lens, each fibre being parallel to their radii, and consequently meeting at an acute angle. In another figure, 95, he represents what he calls *ramifications from the margin of the crystalline lens*, that is, *ramifications* of fibres, a structure which is wholly incompatible with his fig. 93, showing *the order of the fibres of the human crystalline*. No other observer has seen such an arrangement of fibres either in the human crystalline or in any other lens. It is obvious, indeed, that Dr. Young did not possess a correct method of tracing the fibres to their origin, because he makes their arrangement in Fishes similar to their arrangement in Birds, that is, extending from pole to pole like the meridians of a globe ‡, a structure contrary to the results obtained by every observer.

In his 'Icones Oculi Humani,' Sœmmering § has given two very minute drawings of the crystalline; and has inferred merely from its mode of splitting after maceration in alcohol, that it divides into *four* unequal segments, and that in each of these *four* there are four fissures; and though he afterwards found that by "a careful and continued maceration" in alcohol it separated into fibres, yet he argues that this is no proof that the recent or the living lens has a fibrous structure "like the zeolites!" Had he been acquainted with the existence of teeth in each fibre by which they are held together to give solidity and permanence of form to a soft and semifluid body, he could not have considered, as he does, the crystalline lens to be merely a lenticular humour "like a drop of dissolved gum ‖."

In consequence of these contradictory opinions respecting the structure of the human crystalline, I was anxious to study it by means of the optical method which had occurred to me of tracing the fibres to their origin by the diffracted images which they produced.

In some lenses, the age of which I did not know, I found *three* septa, as in quadrupeds.

In two very large lenses there were on each side *four* septa, two being placed at each end of a central line, like that which forms the two septa in the *Hare* and *Salmon*. This structure is shown in the Phil. Trans. 1836, plate 6. figs. 3, 4, but in the human lens the central line was very much shorter than in these figures. The

* Lentis crystallinæ structura fibrosa. Preside Reil. Defendit Samuel Godofredus Sattig, Silesius. Halæ, 1795, p. 14, 29.

† Phil. Trans. 1800; or Elements of Nat. Phil. vol. ii. p. 605. plate 12. fig. 93.

‡ Phil. Trans. p. 605. fig. 100.

§ Francofurti ad Mœnum, 1804, p. 67. tab. 5. figs. 17, 18.

‖ Instar gummi liquefacti. Icones, &c. p. 68.

structure, however, was so distinct, that I could measure the length of the central line, which was 0·0533, or $\frac{1}{19}$ of an inch.

In four lenses which I examined three days after death, I observed *ten* septa on each side, but they had no resemblance whatever to the figure given by Dr. Young. The groups of fibres or vortices were like those of quadrupeds, with this difference, that the septa to which they were related were longer and much nearer the margin of the lens. These lenses were taken from male and female subjects about forty years of age.

More recent observers have found equal difficulties in determining the true structure of the human crystalline. Mr. Nunneley*, in his valuable paper on the crystalline lens, lately published in the Microscopic Journal, makes the following remarks:—

"In the human lens the arrangement of the fibres is the most complicated of any, for while the type is the *mammalian tripod*, and is best seen in the fœtus, in the adult the planes are more numerous, in consequence of the primary planes immediately branching into secondary, so that a very complicated curvature of fibres exists; the septa upon the two surfaces frequently not being equal, those of the posterior being more numerous than those of the anterior. In the anterior *nine* septa and radiations are often found, in the posterior surface *twelve*, which Arnold regards as the more common arrangement in man. This complicity, however, is only in the more superficial layers, for towards the axis the normal mammalian triseptal division is preserved†."

Mr. Nunneley does not inform us whether the statement that the structure varies in the same lens is founded on his own observations or on those of Arnold. Mr. Nunneley's mode of observing consists in "immersing the lens for a few minutes in water at 180° Fahr.," and after allowing it to dry in a warm room, he observes the number of sections into which it splits, and upon the supposition that it splits only in the direction of the septa, he infers the number of the septa from the number of these directions. We cannot place much confidence in results thus obtained. The lens, we think, should be studied in its entire state by following to their origin the converging or parallel fibres, by observing the changes in the diffracted spectra which they produce. By removing in succession the external layers, it will be easy to determine whether or not the structure changes in the layers near the axis.

On the Crystalline Lens of the Cuttle fish. *By* Sir David Brewster, *K.H., F.R.S. L. & E.*

The crystalline lens of the Cuttle-fish differs in a remarkable degree from that of all other animals. Cuvier does not seem to have examined its structure. In his Memoir on the Mollusca, he merely gives a drawing of its external form, and mentions that it consists of two parts easily separated,—the anterior part being more convex than the posterior. In the new edition of his 'Lectures on Comparative Anatomy,' published in 1845, the editors, MM. Frederick Cuvier and Laurillard, have repeated almost *verbatim* the description of the lens given in the original memoir ‡.

Valentin, in Wagner's 'Icones Zootomicæ §', has given a section of the crystalline lens of the Cephalopods, which is repeated in Victor Carus's 'Icones Zootomicæ ‖.' In this drawing the lens is represented as a sphere, the anterior part being much larger than the posterior. In his 'Lectures on Comparative Anatomy and Physiology of the Invertebrate Animals¶,' Professor Owen describes the lens as Cuvier does, as consisting of two distinct parts, the anterior or smaller moiety being the segment of

* In his more recent work, 'On the Organs of Vision, their Anatomy and Physiology,' plate 5, figs. 7 and 8, Mr. Nunneley has represented the human crystalline as having *nine* septa in its anterior, and *twelve* in its posterior surface.

† Journal of Microscopal Science, April 1858, No. 23, p. 150.

‡ I have not seen the memoir of Muller in the 'Annales des Sciences Naturelles' for 1831, on the structure of the eyes of the Mollusks; but as MM. Fred. Cuvier and Laurillard refer to it, I presume that it contains no additional information on the structure of the lens of the Cuttle-fish.

§ Tab. 29. fig. 42. ‖ Tab 23. fig. 1. Leipzig, 1857. ¶ Sect. 24. p. 620. London, 1855.

a larger sphere, and the posterior that of a smaller sphere*; and he adds, what is not correct, that "the lens presents the same denticulated fibrous structure, arranged in concentric laminæ, as in the higher animals." Siebold† gives nearly the same account of the crystalline, the lens being spherical, and the anterior of its two halves less convex than the posterior. Mr. Wharton Jones considers the lens as "a sphere divided into two unequal segments, an anterior smaller and a posterior larger‡."

In studying the crystalline lenses of animals about twenty-five years ago, I had occasion to examine several lenses of the Cuttle-fish, but having found a considerable difference in the structure of different lenses, and not knowing the species from which they were taken, I did not publish my observations in the memoirs which I sent to the Royal Society in 1833 and 1835. As the subject, however, is a very interesting one, and as the attention of anatomists has been lately directed to the structure of the crystalline lens, I have ventured to submit to the Section a short account of my observations.

In the greater number of lenses which I have examined, and which I believe were those of the *Sepia Loligo*, the lens was not a sphere, as maintained by the greater number of the anatomists to whom I have referred, nor did it consist of two *spherical* segments of unequal convexity.. Its posterior and larger portion was decidedly a *paraboloid*, and its anterior and smaller portion a spherical meniscus, whose concave surface coincides with the convex surface of the section of the paraboloid. This remarkable form of the lens is represented in fig. 1, where ABC is the axis of the lens, ADCE a section of the whole lens through the axis, DBE the convex surface of the paraboloid, which is spherical, and MNOP (fig. 2) the spherical meniscus, whose

Fig. 1.—The whole lens.

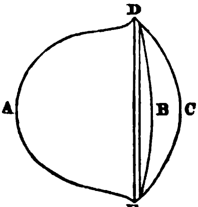
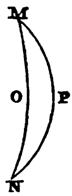


Fig. 2.—The anterior lens.



concave surface MON has the same curvature as DBE, the anterior face of the paraboloid.

The following are the dimensions of the various parts of *three* lenses :—

inch. *First lens.*

AB=0·3433, DE=0·51, AC=0·433.
MN=0·333, BC=OP=0·09.

Second lens.

AB=0·333, DE=0·50.

Third lens.

AB=0·30, DE=0·457.

In some indurated lenses I have found the spherical surface MON slightly convex, and the corresponding surface DBE similarly concave; but I cannot decide whether this structure is *abnormal*, or that of lenses belonging to different species of the Cuttle-fish. That it was not produced by induration, will appear from the following description of indurated lenses which have been in my possession for twenty-five years, in all of which the faces DBE are convex, and the faces MON concave.

1. AB=0·29, DE=0·433.
2. AB=0·235, DE=0·37.
3. AB=0·19, DE=0·27.

* This description is inconsistent with the drawing (fig. 224), which represents the whole lens as a sphere. In this figure the central part of the lens is represented as not lamellar as its structure.

† Anatomy of the Vertebrata, p. 283. Boston, 1854.

‡ Phil. Mag. Jan. 1836. vol. viii. p. 1.

The paraboloidal part of the lens, viz. ADBE, consists of paraboloidal laminæ, the surfaces of which are *perfectly smooth, and give no diffracted images by reflexion* like the surfaces of the laminæ of other lenses. The spherical portion, MNOP, consists of spherical laminæ of the same character. The structure of both portions of the lens is fibrous, the fibres diverging from poles in the axis of the lenses, that is from one pole in each lamina of the two lenses. The fibres, however, must be perfectly flat in order to compose laminæ perfectly smooth; and I have not been able to observe that they are united by teeth as they are in other animals. They must adhere, therefore, to each other by the contact of their surfaces merely, or by some structure not visible in the microscope, and not showing itself by its action upon light.

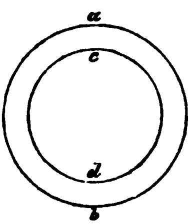
The thin transparent membranes which cover the anterior convex surface of the paraboloid, and the concave surface of the spherical meniscus, have also a fibrous structure, the fibres diverging from a single pole in the axis of the lenses. The surfaces which these membranes cover are the ends of all the fibres which constitute the lens; and each lamina terminates in a sort of ring or margin which is well defined. This ring is a little larger in diameter than the proper section of the paraboloid, and the consequence of this is that the fibres, or the termination of the laminæ, are curved upwards, so that their surfaces are concave near the line DBE.

The two lenses are curiously united. The concave surface MON is less than the convex one, DBE, and there is a notch between D and M going round the lens. The meniscus is kept in its proper place, in contact with the paraboloid, by a ring *abcd* (fig. 3), in which $ab=0{\cdot}50$ of an inch, and $cd=0{\cdot}31$.

In the *Sepia Eledona* the whole lens is nearly spherical, as shown in fig. 4, the

Fig 4.—*Sepia Eledona.*

Fig 3.—Ring DE.



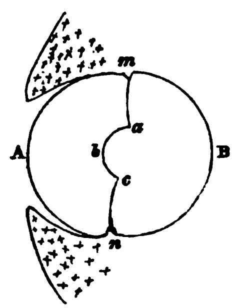
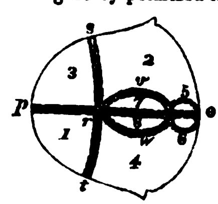


Fig. 5.—Figure by polarized light.



axis or diameter AB being a little larger than *mn*, whereas in the *Sepia Loligo* it is smaller. The lens divides into two parts along *mabcn*, *abc* being a hemisphere about the $\frac{1}{13}$th of an inch in diameter. The whole annular surface, from the circumference *mn* to *a*, *c*, is covered with two membranes, to which the ciliary processes are attached.

In order to examine the polarizing structure of the lens, I made a section of it by two planes parallel to the axis, so that the plate was about the 15th part of an inch thick. When immersed in oil, it gave, in polarized light, the figure shown in fig. 5, when the axis of the lens *po* was parallel or perpendicular to the plane of polarization. The tints to the left of *v* and *w* were the highest, namely the *yellow* of the first order. The sections 1, 2, 3, 4 are *negative* in reference to *r*, and 5, 6, 7, 8 are also negative in reference to the intersection between 6 and 7. When the polarized light is transmitted along the axis of the eye, a black cross is seen, as in uniaxal negative crystals; but the cross opens upon turning round the section, indicating a defect of symmetry in the substance of the lens round the axis. The luminous portions at 5, 6 are very bright.

When the lenses are quickly dried, the laminæ separate from each other, and the lenses have the appearance of pearls; the resemblance is so great, that when the experiment is well made, it is difficult to distinguish them from real pearls, as will be seen in the accompanying specimens*.

* These specimens were exhibited to the Section.

In many of these lenses the laminæ are separated in some parts and not in others, and the consequence of this is, that when we look at the convex surface of the paraboloid by reflected light, we observe a number of luminous and dark rings surrounding the axis of the lens, the luminous rings being produced by the total reflexion of the light from one or more of the separated surfaces. The effect thus produced is very beautiful, as will be seen in the specimens on the table.

The preceding observations were made, as I have already stated, nearly twenty-five years ago, and I have copied them as they stand in the Journal of my Experiments. I observe, however, some discrepancies between the figures and their descriptions, arising, I think, chiefly from not being able to distinguish the lenses of one species from those of another. These discrepancies I hope to be able to reconcile before this communication is published.

On the Use of Amethyst Plates in Experiments on the Polarization of Light. By Sir David Brewster, *K.H., F.R.S. L. & E.*

In order to determine the exact position of the plane of primitive polarization, it was usual to observe when the intensity of the extraordinary image of the analysing prism was a minimum; but as it is difficult to obtain light perfectly homogeneous, the light of this image could not be completely extinguished. In his experiments on the rotatory phenomena of quartz, M. Biot employed a coloured glass, which transmitted only the extreme red rays of the spectrum; but this method, owing to the great loss of light in the polarized pencil, was attended with so many inconveniences, that fifteen or twenty trials were required before he could determine the zero of his instrument. In order to remedy this evil, M. Soleil interposed between the polarizing apparatus and the analysing prism two plates of quartz of equal thickness, the one right-handed and the other left-handed. These plates were united so as to give the same tint when the plane of the principal section of the analysing prism coincided with the plane of primitive polarization. This ingenious apparatus was submitted to the Academy of Sciences on the 23rd of June, 1845, and has been used since that time by M. Senarmont and others in their experiments on polarization. In the year 1819 I communicated to the Royal Society of Edinburgh the very same method of placing the principal section of the analysing prism in the plane of primitive polarization; but in place of using two plates of right and left-handed quartz, I used a single plate of amethyst, in which the two kinds of quartz were combined, during the formation of the crystal. This piece of apparatus, which is obviously superior to that of M. Soleil, is thus described in the paper to which I have referred:—"The properties of amethyst, which have now been described, render a plate of this mineral a valuable addition to our apparatus for conducting experiments on the polarization of light. If we wish to place the principal section of the analysing prism exactly in the plane of primitive polarization, we have only to interpose a thin plate of amethyst like that shown in the figure, and if the tints of both sets of veins are exactly similar, the analysing prism will have the required position. If the one set of tints is bluer or whiter than the other, or if there is the slightest difference between them, the position of the prism must be altered till that difference is no longer perceptible. If we wish to place a plate of sulphate of lime or any other crystal, so as to have its principal section in the plane of primitive polarization, the interposition of the amethyst plate will give us the same assistance, by indicating that the circular (rotatory) tints are not affected by it; whereas if we wish to place the axis of the sulphate of lime at an angle of 45° to the primitive plane of polarization, the amethyst will point out this position when the opposite circular tints suffer an equal change."

On Professor Petzval's *New Combination Lens.*

Sir David Brewster laid before the meeting a paper, translated by Mr. Paul Pretsch, entitled "Prof. Petzval's New Combination Lens, as an Object-glass for Telescopes," and exhibited a fine telescope for which the lens had been originally constructed. This telescope was constructed for the Imperial General Survey Office at Vienna, for the purpose of making maps, and the lens which it contained has been found to be the very best that has yet been constructed for the purposes of photography.

Sir David Brewster gave a brief analysis of this long and interesting communication, of which the following is the conclusion :—" What I have offered is a kind of universal instrument, consisting of three achromatic lenses. The front lens, in connexion with a little larger posterior lens, and mounted like an ordinary portrait lens, reproduces a strongly illuminated and well-defined picture of the usual size. The same front lens, in connexion with a smaller posterior lens, reproduces a large picture with perfect perspective, equal distribution of light, and equal sharpness of the picture. It forms a combination for multifarious applications, for taking views, groups of persons, maps," &c.

On an Apparatus for exhibiting Optical Illusions of Spectral Phenomena. By Henry Dircks.

The author, after quoting some passages in Sir David Brewster's 'Natural Magic,' in which the author had intimated that reflexion by concave specula must form the basis of all spectral illusions by reflexion, and pointing out the inconvenience of using these for producing images of living and moving persons, in consequence of their inverting objects, stated that he had contrived a means by which living actors, some the real persons, others the images of persons concealed from the direct view of the spectators, might be formed by a large plate of glass dividing the room in which the exhibition was made, the spectators being in a darkened portion above, but at one side of the glass plate; while the living persons on the other side of it could be seen quite clearly through the glass, and the images of other persons, walking about in the room under them, seen by reflexion, would appear in the same place as the living persons seen directly, such arrangement becoming, in fact, a transparent mirror, and the actors could be thus made to appear to perform most amusing spectral feats, such as passing through walls, into and coming out of the living actors, and so on.

On a New Case of Binocular Vision. By the Rev. J. Dingle.

The author remarked, that without some provision imperfect vision would continually arise from the difference of the pictures in the two eyes. Even in the same object, the point looked at is often visible only to one eye, and the picture of it is combined in the sensorium with the picture of another part; and in other cases the superposition of different images would sometimes lead to great inconvenience and confusion. It sometimes happens, for instance, that in looking at a field of view at some distance, objects considerably nearer are so interposed as to present themselves in the picture formed in one eye and not in the other. Thus, in looking at a landscape, if the finger or any other object is held before one eye, the image of it from the one retina is superposed in the *sensorium* on a part of the landscape formed in the other eye. On mere physical principles, this might be expected to blot out or greatly confuse that part of the landscape upon which it was placed; but upon trial this is not found to be the case, as that part is merely a little dimmer than the rest from being seen only with one eye, but is equally distinct and as truly coloured. By various experiments the author had ascertained that this was the result of a peculiar power of the will, by means of which the mind is enabled, when two different images are superposed in the *sensorium*, to select whichever it pleases, to bring that object into view, and entirely to obliterate the other,—it sees, in fact, whichever it wills to see, and the other image, simply by being neglected, becomes invisible. In ordinary vision, the determination of the image to be seen is effected by the same act of the will which determines the position of the optic axes; but by certain arrangements which were indicated, both images may be made to have the same relation to the optic axes; and as the predisposition to select one or the other is thus obviated, it is made indifferent to the mind which of the two images that occupy the same place in the *sensorium* it shall see*. When these arrangements are made, it is found that

* The proof of the law might be allowed to rest on an accurate observation of what is almost constantly taking place in the act of vision; but the following simple experiment may

mere efforts of the will can easily bring either the one or the other into view. The importance of this law, which enables the mind to select its image, was pointed out in different cases of ordinary vision. It obviates the difficulty already adverted to, of having two different pictures on the same spot; it has not improbably an important influence in producing the general stereoscopic effect; it also, to some extent, remedies the effect of squinting, by obliterating the picture in the imperfect eye, which could not be else done without shutting it. The effect of the law, in some extraordinary cases, was also noticed, especially in the power of the will to fix images on the sight, as Sir Isaac Newton instances in his own case (see his 'Life,' by Sir David Brewster). The author pointed out the great interest of the subject, not only in its practical aspect, but also as having an important bearing on the connexion between mind and matter.

On some Optical Properties of Phosphorus.
By Dr. Gladstone *and the* Rev. T. P. Dale.

The authors had recently examined the effect of temperature on refraction by means of the instrument constructed by the Rev. Baden Powell, from a grant of the British Association. They had extended their examination of the optical properties of phosphorus to other points. Solid phosphorus at 25° C. gave the following refractive indices :—

Fixed line A	2·1059
„ „ D	2·1442
Extreme violet	2·3097

This shows an amount of refraction only just exceeded by diamond or chromate of lead, and an amount of dispersion perhaps unapproached by that of any other substance.

Melted phosphorus at 35° C. gave the indices—

Fixed line A	2·0389
„ „ D	2·0746
„ „ F	2·1201
„ „ G	2·1710
Extreme violet	2·2267

This shows a considerable diminution both of the refractive and dispersive power. At the temperature of 35° C., the refraction of the orange ray through solid phosphorus was to that through the liquid body in the ratio of 2·117 to 2·071.

The change of refrangibility caused by change of temperature is greater with liquid phosphorus than with any other known body. A saturated solution of phosphorus in bisulphide of carbon is almost as refractive and dispersive as the element itself. Refractive indices for the principal fixed lines of the spectrum, as seen through such a solution, were given. There is a certain indistinctness about the prismatic image seen through phosphorus not depending on opacity or crystalline structure, and not arising from the high refraction or dispersion, nor wholly from the great sensitiveness to changes of temperature. It may be connected with the well-known allotropic variations of this body, no particular specimen being really homogeneous. The phosphorus experimented on was colourless; yellow phosphorus cuts off the red rays. The white flame of phosphorus contains all the visible rays of the solar spectrum, but exhibits no trace of any dark line or band.

A Hand Heliostat, for the purpose of flashing Sun Signals, from on board Ship or on Land, in Sunny Climates. By F. Galton, *Sec. R.G.S.*

A flash of sunlight from a looking-glass, of a few inches in the side, can be seen

assist in making it apparent. Let a person stand before a papered wall with pictures hanging on it, and shift the optic axes so as to bring different patterns of the paper together. The images of the pictures formed in the two eyes will then be separated in the sensorium, and shifted off upon the image of a part of the paper; and if the attention is turned upon these parts, it will be found that it may be made to depend on an effort of the will whether the picture or the paper will be seen there. The experiment might be still better made with a suitable piece of a different paper pinned on the wall; as in the case of pictures, the more interesting or much brighter objects are apt to force themselves too much on the attention.

further than any terrestrial object whatever; and the instrument about to be described shows how this remarkable power may be utilized for the purposes of telegraphy. Heliostats are used in all Government surveys, and their power is well known in penetrating haze, and their utility in requiring no "sky line." They were also habitually employed by the Russians for telegraphy during the Crimean war. But all heliostats that have been hitherto used have been fixtures of large dimensions; commonly, a shaded screen, with an aperture in it, was placed at many yards from the signaller, who stationed himself in such a way that when he could see the play of his flash about the hole in the screen, he might be sure that some of the rays which passed through the aperture would be visible at the distant station. At other times, a polished ring was used for the same purpose as the screen, but the principle was the same. The present instrument dispenses with all fixture; it is more portable than a ship's telescope and as manageable as a ship's quadrant, and may be made by a carpenter for 4*s*., if he possesses a convex spectacle-lens of short focus and a piece of good looking-glass. The looking-glass attached to the heliostat is about 3 inches by 4½ inches, and therefore capable of being seen at distances, which may be calculated from the fact, that a mirror 1 inch square is perfectly visible, in average sunny weather, at the distance of 8 miles, and that it shows as a brilliant and glistening star at 2 miles. Before describing its principle and action, it will be necessary to explain clearly the peculiar characteristic of the reflexion of the sun's rays from a mirror. If, for instance, we take a small square looking-glass and throw its flash upon a wall 2 or 3 feet off, the shape of the flash will be little different from that of the mirror itself, seen in perspective; but if we direct it on an object 3 or 4 yards off, the angles of the flash will appear decidedly rounded; at 20 or 30 paces it will appear fairly circular; and if we can manage to see it at 50 or 100 yards (which can only be effected by selecting some object to throw it on, that is naturally of a light colour, but lying under a dark shade), it will appear like a mock sun, of identically the same shape and size as the sun itself; and for all greater distances the appearance remains the same. That is to say, whatever may be the shape or size of the mirror, and whatever the irregularity of the distant objects on which the flash happens to be thrown, the shape and size of that flash, if it could be seen by the signaller, would always appear to him as exactly that of the sun. In fact, the flash forms a cone of light, at the blunted apex of which are the mirror and the signaller's eye, and whose vertical angle equals that of the sun's angular diameter. Whoever is covered by the flash sees the mirror, like a small fragment of the sun itself, held in the hand of the observer; and the larger the mirror, compared to the distance, the larger and the more dazzling does it appear. Now, the hand heliostat provides a bright appearance of the sun, which, when the instrument is adjusted and looked through, overlays the exact area which is covered by the flash of the mirror, which is attached to its side. It is a perfect substitute for that mock sun which we can see at 50 or 100 paces distant, but which becomes too faint to be traced much further. All we have to do, when we wish to send a flash to a distant object, is to make that image of the sun overlay the object, just as may be done in rough sextant observations. The principle of the instrument is extremely simple. A convex lens, of any focal distance (5 inches is convenient), has a small screen attached to it, whose surface is at its focal distance. The mirror is so placed that a small portion of its flash impinges upon one end of the lens; say, the right-hand side of it. The signaller's eye looks partly through the other end of the lens, and partly free of it. Now the rays from any one point of the sun's surface are converged by the right side of the lens to a bright speck on the screen; and those rays which radiate from that speck and impinge on the left side of the lens are brought back by means of it to a state of parallelism with the rays that originally left the mirror. Consequently the signaller's eye sees the bright speck in the precise direction of the vanishing point of the mirror's flash, and he can, by looking partly to the side of the lens, refer it to some particular spot in the distant landscape. But what is true for any one point on the sun's disc is true for every point, and accordingly we obtain a bright disc upon the screen, which appears of exactly the same shape and size as the sun itself, and necessarily overlays the exact area covered by the flash of the mirror. It is scarcely possible to describe the instruments that were submitted to the Association without drawings. They consisted of a tube of wood 15 inches long, and with an eye-hole at one end; a mirror turned on an axis at right angles to the tube; and, in front of the mirror, a slip was cut away from the side of the tube, and the lens was inserted athwart the cut-out part. Part of the lens projected within the tube, and part outside of it and in front of the mirror. The screen was placed at the further end of the cut-out part, and an envelope protected the whole from injury. A slide in front of the lens regulated the amount of light thrown on it, and toned the image to the required degree of brightness. The addition of a telescope was not found practically of much use; neither was that of a second mirror, for double reflexion, to meet the difficulty of sending signals when the sun was behind the back of the signaller. It is not difficult to signal within 12° of the point opposite to the sun, and it is possible to do so within 7°. The looking-glass should be of the very best plate-glass, and it ought to have its sides truly parallel, else there will be a confusion of images and an irregularity in the flash. Letters are conveyed by treble groups of flashes, each of which groups consists of one, two, or three flashes, as the case may be.

The author detailed the experiments he had made with the help of an assistant, and trusted that a full trial of the instrument at sea would be made by the authorities of the Navy, with a view of determining whether it should not be accepted by them as a subsidiary signalling instrument throughout Her Majesty's Service. One of the land heliostats has been sent to the United Service Institution, in Whitehall Place, together with a more detailed explanation.

On the Fixed Lines of the Solar Spectrum. *By* J. H. Gladstone, *Ph.D., F.R.S.*

The author exhibited maps of the fixed lines and bands seen in the solar spectrum between those usually designated A and B, and of those which he succeeded in seeing beyond K. The light examined was that of the full sun at noon about midsummer-day. The dark lines and bands in the lavender rays coincided with those drawn by Prof. Stokes, as occurring in fluorescent phenomena; and with those of M. Becquerel, which occur in the photographic image; but the author's map contained many finer ones. It extended to M. Becquerel's N. Another map was exhibited of the dark lines and bands that make their appearance in the orange and yellow rays when the sun is near the horizon, as previously described by Sir David Brewster. The long space of air traversed by the sun's rays when setting also absorbs the more refrangible rays, but makes no difference in the angular position of the fixed lines themselves. The light of the moon exhibits the same black lines, and, when close to the horizon, it shows the additional lines in the orange in the same angular position. The light of the moon, answering in position to the violet rays of the sun, appears lavender, and even grey, like the most refracted rays of the sun. As to the origin of these lines, Dr. Gladstone had endeavoured to determine whether they were due to the absorbent power of the earth's atmosphere, as the lines in the orange appear to be. Fraunhofer's conclusion, that they do not occur in the light of some of the fixed stars, was thought to be open to objection; but the author's observations on the light of the stars had not led him as yet either to a positive or negative result. Artificial lights seen at a very great distance might determine the point. If these fixed lines are dependent on the sun's atmosphere, they ought to be darkest in the light coming from the edge of the sun's disc; but the author had been unable to find any difference between rays proceeding from different parts.

On the Influence of Light on Polarized Electrodes. *By* W. R. Grove, *M.A., F.R.S. &c.*

The author, soon after the publication of Daguerre's experiments, had shown that when light is allowed to impinge on a prepared daguerreotype plate in water, a voltaic current is evolved which affects the galvanometer. In the present experiments, two platinized platinum plates are placed in dilute acid, and the one exposed to sunlight while the other is in the dark. A current is detected by a galvanometer connected with the plates, which, after many experiments, the author found was dependent upon the original polarization or unequal chemical action on the electrolyte, the current being (with certain exceptions noticed in the paper) in the same direction as that indicated by the original deflection of the galvanometer when it is first connected with the plates. Experiments are given with other solutions producing the same results. To prove that it is not an effect of heat, it is shown that non-luminous heat alone does not produce the effects, and that when the sunlight is made to pass through coloured glasses before impinging on the plate, blue light produces a greater deflection than yellow or red, showing that the results are due to the chemical, and not to the calorific rays of the sun. The effects appear therefore to be due to an augmentation by the impact of light of the electro-chemical action taking place at the surface of the plates, the chemical action being doubtless due, as in the known cases of polarized electrodes, to heterogeneous films on the surface.

On a New, Cheap, and Permanent Process in Photography. *By* W. M'Craw. (*Communicated by* Sir David Brewster.)

I now set myself to repeat in writing the mode I use for producing the specimens which attracted your notice to-day, of permanent photographic prints, produced without either silver, gold, or the noxious hyposulphite of soda. I need not expatiate to you upon the advantages of such a process. It is, indeed, felt to be the great photographic desideratum wherever photography is practised—and that is nearly all over the world—particularly by the conscientious photographer and the considerate collector of photographs. The labours of the Committee appointed by the Photographic Society of London, to inquire into the cause of the fading of photographs after a lapse of two years, have only amounted to this,—that photographs of a certain kind have all faded; and that some of those of the kind that have stood best have unaccountably faded,—the sad presumption being, that in time all photographs produced in the usual way, by the means of chloride of silver, and fixed (as it is called) by hyposulphite of soda, will perish. These considerations, and the fact of a prize being offered by a French nobleman for the discovery of a process for printing photographs in carbon, set me to experiment in that direction. But my experiments with carbon and various pigments led me to think that no material applied mechanically, or that could not be made to take the shape of a dye or chemical solution, would ever give results with the exquisite half-tints of the present beautiful but perishable process. The photographic properties of bichromate of potass were pointed out by Mr. Mungo Ponton twenty years ago, giving photographs of a pale tawny colour. A piece of paper is washed over with the saturated solution of the bichromate, and when dried in the dark is of a bright yellow colour, and very sensitive to light. If a negative photograph, or a piece of lace or a leaf, be placed over the prepared paper, and put in sunshine, in a few minutes a perfect impression of the object is obtained. The light darkens the colour of the bichromate, and renders it insoluble in water, while the yellow colour may be washed out from the parts protected from the light by the lace or leaf, or negative photograph, as the case may be. But pictures of this kind have little or no practical value; for although the lights are good enough, the deep black shadows are only represented by a tawny shade. Some eighteen months ago a process was patented for deepening these photographs by treating them with gallic acid and a salt of iron, which went by the name of 'Sella's process.' I tried this process at the time according to the specification of the patent, but failed to make one satisfactory specimen. They wanted everything that a good photograph should have,—pure lights, clear half-tints, and deep shadows; and as I found that others had not been more successful, I abandoned my experiments. But in the course of further experiments, a year afterwards, with carbon, I was struck with the fact, that when a drop of a solution of bichromate of potass was allowed to fall on a piece of white paper and afterwards dried and exposed to the sun, when washed with a solution of protosulphate of iron, and then with gallic acid, while the spot became perfectly black, the surrounding white paper was unaffected by the liquids. Knowing the photographic properties of the bichromate already described, I believed that this might be the foundation of a good photographic process; and that if the bichromate could be kept from penetrating the pores of the paper, by being kept on its surface, the defects of Sella's process might be avoided. With this view, I began by filling the pores of the paper with albumen, and then to render it insoluble, immersing the paper in ether. This, however, did not answer. But as it would be tedious to detail all the pains I took to discover what would not do, and to find in what proportions and in what order the right materials could be best applied, I will briefly give the formula which I have adopted, and by which the specimens alluded to were produced:—First, take the white of eggs, and add 25 per cent. of a saturated solution of common salt (to be well beat up and allowed to subside); float the paper on the albumen for thirty seconds, and hang up to dry. Secondly, make a saturated solution of bichromate of potass, to which has been added 25 per cent. of Beaufoy's acetic acid; float the paper on this solution for an instant, and when dry it is fit for use: this must be done in the dark room. Thirdly, expose under a negative, in a pressure frame, in the ordinary manner, until the picture is sufficiently printed in all its details,—but not over-printed, as is usual with the old process. This requires not more than half the ordinary time. Fourthly, immerse the pictures in a vessel of water in the darkened room; the undecomposed bichromate and albumen then readily leave the lights and half-tints of the picture. Change the water frequently, until it comes from the prints pure and clear. Fifthly, immerse the picture now in a saturated solution of protosulphate of iron in cold water for five minutes, and again rinse well in water. Sixthly, immerse the pictures again in a saturated solution of gallic acid in cold water, and the colour will immediately begin to change to a fine purple-black. Allow the pictures to remain in this until the deep shadows show no appearance of the yellow bichromate; repeat the rinsing. Seventhly, immerse, finally, in the following mixture:—Pyrogallic acid, two grains; water, one ounce; Beaufoy's acetic acid, one ounce; saturated solution of acetate of lead, two drachms. This mixture brightens up the pictures marvellously, restoring the lights that may have been partially lost in the previous parts of the process, deepening the shadows, and bringing out the details; rinse, finally, in water, and the pictures are complete when dried and mounted. The advantages of this process may be briefly stated as follows:—First, as to its economy;—Bichromate of potass, at 2*d*. per ounce, is substituted for nitrate of silver at 5*s*. per ounce. Secondly, photographs in this way can be produced with greater rapidity than by the old mode. Thirdly, the pictures being composed of the same materials which form the constituent parts of writing-ink, it may be fairly inferred that they will last as long as the paper upon which they are printed. A beautiful photograph of Sir Walter Scott's monument, obtained by this process, was exhibited to the Section.

On Moon Blindness. By Sir G. Robinson.

The author gave several instances of his men who had slept on deck exposed to the moonbeams being so blind on landing that they had to be led by the hand. Also the sailors were in the habit of waking up the soldiers who attempted to sleep on deck, and warning them that they would be blinded.

On an early form of the Lenticular Stereoscope constructed for the use of Schools. Exhibited by Mr. Samuel, *Edinburgh.*

It consists of two semilenses on a frame, from the middle point between which there extends a brass rod upon which the stereoscopic picture slides, so as to have two adjustments; one along the rod for persons of different ages; and one of a rotatory kind, to place the horizontal lines in the picture parallel to the line joining the two eyes, an adjustment which exists in no other form of the stereoscope. This instrument is described in Sir D. Brewster's 'Treatise on the Stereoscope,' p. 69.

On the Ocular Crystal Micrometer, with observations of twelve double stars, as evidence of its extraordinary power in measuring small angular distances. By Norman Pogson. (*Communicated by* John Lee, *LL.D., F.R.S.*)

The instrument which it is the object of this paper to recommend to the notice of astronomers, is of such easy application, yet capable of yielding such extraordinarily accurate results when applied to the measurement of small distances, that it appears singular, as well as a matter of regret, it should so long have awaited a fair trial, and the publicity it so well deserves.

Although copiously described by Dr. Pearson in his valuable work on 'Practical Astronomy,' so many varieties of double-image and other micrometers are there treated, that the one under consideration has failed to attract more than a passing notice from the Doctor's readers, and unfortunately *no published results* have made their appearance from which amateurs might judge of the accuracy attainable by its use. Had such been forthcoming, doubtless the Ocular Crystal Micrometer would have been generally adopted, and the well-grounded complaint, of the inferiority of the measures of distance of double stars to those of the angles of position, would never have been heard of.

Perhaps the best method of drawing attention to this micrometer will be briefly to explain the construction and use of one, originally made for Admiral Smyth,—transferred by him to the Hartwell Observatory in 1829, on becoming possessed of the larger one described in his 'Celestial Cycle,' and recently placed in the hands of Mr. Pogson for trial, by the kindness of its present owner, Dr. Lee.

The Ocular Crystal Micrometer consists of a variable eyepiece, *i. e.* one in which the second or field-lens is moveable by a rack-work, so as to vary the distance between it and the eye-lens. This distance is read off, by the help of a vernier, on a scale of equal parts, and this, as will be shown, is an important element in the observation. By a well-known optical formula, if e, f, and O represent respectively the focal lengths of the eye-lens, field-lens, and object-glass of a telescope, when used with a certain eyepiece, also d, the distance between the first-named lenses, the magnifying power of the telescope with such eyepiece will be thus found:—

$$\text{Power} = \frac{O}{e.f}.(e+f-d).$$

From this it is manifest, that when the two lenses are in contact, the power will be a maximum; that as the distance between them increases, the power will diminish; and that the equal divisions on the scale which records this distance will, when multiplied by the factor $\frac{O}{e.f}$, give the corresponding changes in the magnifying power. It is therefore sufficient to determine, with a dynameter, the magnifying powers when the lenses are in contact, and when most widely separated, and by simple proportion to tabulate the intermediate divisions and corresponding powers. By having two or three eye-lenses, which can be slipped (*not screwed*) into their cells, the range of powers is very considerably increased. Thus in our micrometer, eye-lens No. 1 extends from powers 261 to 134; No. 2, from 135 to 78; and No. 3 from 71 to 48.

To produce a double image, two prisms of rock-crystal—the one cut in the direction of its optical axis, the other transversely thereto—are cemented together, so as to form an achromatic solid of double refraction. Six such prismatic solids, of constant angles from 2474″ to 192″, are in our micrometer fitted into brass caps, which are made to slip on, in *front* of the eye-lens; so that if the separation of the images is too great, the prism can be immediately changed for another of a less constant angle, and *vice versâ*. The double image is therefore formed *after* the telescope has performed its office, and is much cleaner and more distinct than in the original contrivance of Rochon, the inventor, who placed his prisms between the eyepiece and the object-glass. No wings or coronæ trouble the observer as with divided eye-glass micrometers; and although of course half the light is lost by the duplication of the image, the tedious additions of clock motion and illumination of the field are dispensed with. Indeed, the loss of light sustained by the use of illumination barely sufficient to render the spider lines of a wire-micrometer visible, far exceeds that occasioned by the transmission of the rays through good prisms of rock-crystal. Perhaps the whole secret of the excellence of this micrometer lies in the position of the crystal being BEFORE instead of behind the eyepiece.

On viewing a double star through the Ocular Crystal Micrometer, two pairs will be seen, the four members of which must be brought into the same straight line by turning the crystal round in its cell. The measure is then made by varying the magnifying power, *i. e.* the distance between the two lenses, until the four stars appear equidistant. If the power be too small, the middle space will be greater than that between each pair of stars; if too great, the reverse. When the four are, however, satisfactorily adjusted and the scale read off, the measured angular distance is equal to the constant angle of the crystal divided by the magnifying power employed. By placing the four stars at equal intervals, the double distance will be measured, and the uncertainty of a contact between two perhaps very unequally bright stars avoided, which is highly desirable. It is therefore of the utmost importance to know the constant angles of the prisms, also the limits of magnifying power of the variable eyepiece, with all possible accuracy. It does not enter our purpose here to discuss the various methods recommended by Dr. Pearson for determining these instrumental constants; suffice it to remark, that when once found they are not liable to change, and their investigation is by no means difficult.

The observation of position angle, though less certain than that of distance, is at least equal to what can be made with any other kind of micrometer. For this purpose a fine diametral line is cut across the flat side of the field lens, which becomes visible when screwed into the focus of the eye-lens. This line must be adjusted by running the double star, or if more convenient any adjacent bright one, along its entire length. This done, the prism, which is attached to the vernier of the position circle, must be moved round until the two images of the line are seen in coincidence, when the reading will be the zero-point of the position circle. For these two operations the field requires illumination, though not for the absolute measures. The four stars seen through the prism must next be brought into the same straight line, as in the measure of distance, when the difference between the circle-reading and the zero previously found, plus or minus ninety degrees, will give the angle of position. Unless the equatorial adjustments of the telescope have been very correctly made, it is better to take half the number of zero readings before, and half after those of position, so as to eliminate any change of the zero arising from the alteration of hour-angle during the observation.

A temporary defect in our micrometer, which could not be remedied without parting with it just at the time most convenient for its use, prevented the observations of angle of position being made. A few only were attempted, but sufficient to show that good results may be expected in this coordinate also when the micrometer is put into working order. But as the observations appended are to be regarded merely as examples of its capabilities as a distance-measurer, under unfavourable conditions, and by no means in the light of a series of scientific results, it would not be rendering justice either to the instrument or to the observer to add the few imperfect angles of position obtained, and they have therefore been omitted.

No kind of micrometer is so suitable to, or convenient for, an unprofessional astronomer, who cannot enjoy the luxuries of an observatory; and it is no exaggeration of its merits to say, that any good portable telescope, so equipped, will enable its possessor to compete successfully with far larger instruments in fixed observatories not so provided. To prove this point, it is only necessary to refer to the annexed observations of well-known double stars, measured on different nights, frequently with different crystals, and therefore perfectly free from any pre-occupation of mind. As first attempts with a strange instrument, they are naturally open to great improvement; but with practice and care, it seems reasonable to hope that differences exceeding half a second, or for small distances a twentieth part of the measured space, will rarely, if ever occur.

It is a striking proof of the excellence of the Smythian telescope, that with an aperture of only 3·6 inches, with the light diminished by the duplication of the image, and by its transmission through tolerably thick prisms of rock-crystal, powers over 200 were so readily usable. Its definition is beyond all praise: without the prisms, it bears a power of 400 well, and separates the closer double stars in a manner which puts to shame many much larger telescopes.

Distance Measures of Twelve Double Stars with the Ocular Crystal Micrometer.

α Piscium.

Date. 1858.		Prism.	Power.	Distance.	Measures.
Sept.	4.	5	233·3	3″·42	5
„	5.	5	234·4	3·40	5
„	8.	5	218·8	3·65	5
„	9.	5	231·8	3·44	5
„	12.	5	226·7	3·52	5

γ Arietis.

Date. 1858.		Prism.	Power.	Distance.	Measures.
Aug.	12.	5	89·6	8″·91	5
„	13.	5	89·2	8·95	5
„	16.	5	91·4	8·73	5
„	23.	5	91·1	8·76	5
„	25.	5	91·3	8·74	5
„	27.	5	90·8	8·79	5

γ Andromedæ.

Date. 1858.		Prism.	Power.	Distance.	Measures.
Aug.	8.	6	122·3	10″·11	3
„	8.	6	128·0	9·66	8
„	9.	6	123·9	9·99	5
„	11.	6	123·0	10·06	5
„	12.	6	122·4	10·11	5

Castor.

Date. 1858.		Prism.	Power.	Distance.	Measures.
Aug.	8.	6	226·2	5″·47	5
„	9.	5	144·9	5·51	5
„	11.	6	229·0	5·40	5
„	13.	6	233·2	5·31	5
„	16.	6	227·6	5·44	5

ζ Ursæ Majoris.

Date. 1858.		Prism.	Power.	Distance.	Measures.
Aug.	3.	6	85·6	14″·44	3
„	3.	5	55·1	14·50	3
„	5.	5	56·2	14·19	5
„	5.	6	86·9	14·23	5
„	6.	6	87·1	14·21	5
„	7.	6	86·6	14·62	5
„	8.	6	88·8	13·94	3
„	11.	6	87·7	14·11	5

α Herculis.

Date. 1858.		Prism.	Power.	Distance.	Measures.
Aug.	27.	4	110·2	4″·66	5
Sept.	1.	6	255·3	4·85	5
„	4.	4	112·3	4·57	5
„	5.	6	256·6	4·82	5
„	6.	4	111·4	4·61	5

70 Ophiuchi.

Date. 1858.		Prism.	Power.	Distance.	Measures.
Aug.	1.	5	122·1	6″·53	3
„	5.	5	130·8	6·10	5
„	7.	5	129·3	6·17	5
„	7.	6	194·4	6·36	3
„	8.	5	129·0	6·19	4
„	9.	5	127·7	6·25	5

100 Herculis.

Date. 1858.		Prism.	Power.	Distance.	Measures.
Aug.	9.	6	88·7	13″·95	5
„	11.	6	89·4	13·84	5
„	12.	6	88·1	14·04	5
„	14.	6	87·3	14·17	5
„	23.	6	87·9	14·07	5

ε¹ Lyræ.

Date. 1858.		Prism.	Power.	Distance.	Measures.
Aug.	1.	4	171·2	3″·00	2
„	5.	5	253·9	3·14	5
„	6.	5	243·4	3·28	5
„	7.	4	156·0	3·29	5
„	8.	5	249·9	3·19	8

ε² Lyræ.

Date. 1858.		Prism.	Power.	Distance.	Measures.
Aug.	5.	4	202·3	2″·54	5
„	6.	4	204·0	2·52	5
„	7.	4	208·9	2·46	5
„	8.	4	208·7	2·46	5
„	9.	4	202·8	2·53	5

γ Delphini.

Date. 1858.		Prism.	Power.	Distance.	Measures.
Aug.	1.	6	109·1	11″·34	1
„	3.	6	107·0	11·56	3
„	5.	6	108·4	11·41	5
„	6.	6	106·1	11·66	5
„	7.	6	105·9	11·68	5
„	7.	5	69·1	11·58	5

ζ Aquarii.

Date. 1858.		Prism.	Power.	Distance.	Measures.
Sept.	4.	5	231·2	3″·45	5
„	5.	5	233·4	3·42	5
„	8.	5	238·9	3·34	5
„	9.	5	229·7	3·47	5
„	12.	5	230·5	3·46	5

Mean Results derived from the preceding Observations.

Star.	Mean Date.		Power.	Distance.	Probable Error.	Extreme difference of observations.
α Piscium	1858.	Sept. 8.	229·0	3″·49	0″·03	0″·25
γ Arietis............	„	Aug. 19.	90·6	8·81	0·03	0·22
γ Andromedæ	„	Aug. 9.	124·5	9·99	0·06	0·45
Castor	„	Aug. 10.	212·2	5·43	0·02	0·20
ζ Ursæ Majoris ...	„	Aug. 6.	79·7	14·28	0·05	0·68
α Herculis	„	Sept. 2.	169·2	4·70	0·04	0·28
70 Ophiuchi	„	Aug. 5.	136·2	6·24	0·04	0·43
100 Herculis.......	„	Aug. 14.	88·3	14·01	0·04	0·33
ε¹ Lyræ	„	Aug. 6.	224·3	3·20	0·04	0·29
ε² Lyræ	„	Aug. 7.	205·3	2·50	0·01	0·08
γ Delphini.........	„	Aug. 6.	99·0	11·57	0·04	0·34
ζ Aquarii............	„	Sept. 8.	232·7	3·43	0·02	0·13

To arrive at a general conclusion as to the accuracy attainable with this micrometer, agreeably to the *sixty-five observations* here given, we shall find that for the mean power 152·7, and mean distance 7″·67, the probable error of one observation, based upon five measures, will be 0″·086.

Also, if we suppose the accuracy to increase in direct proportion with the power, the extreme difference to be expected amongst *five such observations*, taken with a magnifying power of 200, will be 0″·21.

On the Distribution of Heat in the Interior of the Earth. *By* Dr. F. A. Siljeström, *of Stockholm.*

Both the plutonic and volcanic phenomena are generally ascribed to causes residing within the earth's solid crust, whilst the interior fluid mass is taken into consideration only with regard to what Humboldt calls its "reaction." Without disputing this way of explaining the phenomena—though I really think it liable to several grave objections—I wish to call attention to a cause of dilatation (and contraction) that certainly exists, or at least has existed within the fluid mass itself, and which, I think, must be considered as an important item in this question.

It seems impossible originally not to suppose different temperatures in different parts of the fluid earthy mass. Considering the great absolute temperature, as well as the immense bulk of the earth and other circumstances, differences as great even as 100° C., nay more, can in no way be regarded as improbable. The natural consequence thereof was the formation of *currents*, by means of which differently heated parts were brought together, and the temperature of the mass was made more and more uniform. However, on various grounds I conclude that even now the temperature cannot be one and the same through the whole fluid nucleus of the earth, but that currents of the said description still exist in the interior of our planet.

This assumed, let v, v' be the volumes, and t, t' the temperatures of two differently heated fluid parts, which are mixed together, and which, for more simplicity, may be regarded as having the same mass and as being of the same chemical nature. Let, further, w be the volume and T the temperature of each after the mixture. As both the dilatation and the specific heat change with the temperature, let Δ, e be the mean dilatation and the mean specific heat between the temperatures t and T, and Δ', e' between T and t (t being $> t'$). Hence it follows that

$$v=w\big(\iota+\Delta(t-\mathrm{T})\big)$$
$$v'=w\big(\iota-\Delta'(\mathrm{T}-t')\big)$$
$$(t-\mathrm{T})e=(\mathrm{T}-t')e',$$

and consequently that

$$v+v'=2w+\frac{w\,(t-t')\,(\Delta e'-\Delta' e)}{e+e'}.$$

Now $v+v'$ being the original volume and $2w$ the volume after the mixture, it will be seen that there must needs be a *change of volume*, unless $\Delta e'=\Delta' e$, which at least is *not* the case with the substances, for which Dulong has determined the variations of dilatation and specific heat.

If we take as an example the values found by Dulong for iron between 0°–200°, it will be seen that if only $\frac{1}{1{,}000{,}000}$ of the earth's volume were subject to the above-named process of mixture—one part being considered 200° warmer than the other—the result would be a change of volume certainly not less than five or six times the whole bulk of Vesuvius. This may in some way be illustrative of the *quantity* of action that might be supposed. As to the absolute intensity and the mode of working, I think no other force could be imagined more suited to the purpose.

An Account of some Experiments on Radiant Heat, involving an Extension of Prévost's *Theory of Exchanges.* *By* B. Stewart.

These experiments were performed with the aid of the thermomultiplier, the source of heat being for the most part bodies heated to 212°. Four groups of experiments were considered. Group the first contains those experiments in which the quantities of heat radiated from polished plates of different substances at a given temperature, are compared with the quantity radiated from a similar surface of lampblack at the same temperature. The result of this group of experiments is, that glass, alum, and selenite radiate about 98 per cent. of what lampblack does; thick mica, 92; thin mica, 81; and rock-salt only 15 per cent. The second group of experiments was designed to compare together the quantities of heat radiated at the same temperature from polished plates of the same substance, but of different thicknesses. The result of this group was, that while the difference between the radiating power of thick and thin glass is so small as not to be capable of being directly observed, there is a perceptible difference between the radiation from thick and thin mica, and a still more marked difference between the radiation from plates of rock salt of unequal thickness. The third group of experiments was made with the view of comparing the radiations from various polished plates with that from lampblack, as regards the quality of the heat,—its quality being tested by its capability of transmission through a screen of the same material as the radiating plate. From this group of experiments it appears that heat emitted by glass, mica, or rock-salt is less transmissible through a screen of the same material as the heated plate than heat from lampblack,—this difference being very marked in the case of rock-salt, which only transmits about one-third of the rays from heated rock-salt. The common opinion that rock-salt is equally diathermanous for all descriptions of heat is therefore untenable. The fourth group of experiments shows that heat from thick plates of glass, mica, or rock-salt is more easily transmitted by screens of the same nature as the heated plate than heat from thin plates of these materials. It was shown that all these experiments may be explained by Prévost's theory of exchanges, somewhat extended. This extension consists of the following laws:—1. Each particle of a substance has an independent radiation of its own equal in all directions and without regard to the distance of the particle from the surface of the body. 2. The radiation of a particle equals its absorption, and that for every description of heat. 3. The flow of heat from within upon the interior surface of a polished plate of indefinite thickness is proportional to the index of refraction of the body, and that for every description of heat. The bearing of these experiments on Dulong and Petit's law of radiation was then attempted to be traced. It was shown that unless bodies from simply being heated change their transmissibility for the same description of heat (which there is no reason to suppose), the radiation of thin plates or particles at a high temperature will bear a less proportion to the total radiation of that temperature than at a low,—the consequence will be, that the radiation of single particles will increase with the temperature in a less degree than Dulong and Petit's law would indicate. It may even be that the radiation of a particle or very thin plate may be proportional to the absolute temperature of that particle. Taking a piece of glass or mica, therefore, at a low temperature, as it is very opake with regard to the heat radiated by itself, we may suppose that the total radiation consists of that of the outer layer of particles only, that from the inner layers being all stopped by the outer. At high temperatures, however, we may suppose that there is not only the radiation of the outer layer, but also part of that of the inner layer which has been able to pass, swelling up the total radiation to what it appears in Dulong and Petit's experiments. This way of looking at radiation may possibly bring the radiative power of particles to obey the same laws with the conducting power of particles, which Prof. Forbes has shown decreases with an increase of temperature. The author of this communication is indebted to Prof. Forbes for the use of the instruments and substances employed, and also for many valuable suggestions with regard to the experiments it contains.

Electricity, Magnetism.

On the Intensity of the Terrestrial Magnetic Force. *By* J. Drummond.

In comparing the observations of the dip with those of the intensity, the author found some anomalous results, of which the following is an example. In the diurnal variation the dip is at a minimum about 8 A.M., at a maximum about 11 A.M., after which it decreases to a minimum again about 2 P.M. Turning now to the intensity, the maximum is found to occur about 8 A.M., and the minimum about 11 A.M., after which it again increases, reaching a maximum in the afternoon. From these facts, then, it would appear that, while the earth exerts a greater attracting power over the needle about 11 A.M. than either before that hour or after it, the intensity of the force by which this is accomplished is then at its minimum. In other words, we are driven to the conclusion that the earth exerts a greater attracting power by a minimum of force than by a maximum,—a conclusion entirely at variance with all our knowledge of the magnetic force. This anomalous result the author traced to the assumption lying at the foundation of the present theory of the intensity, viz. that the terrestrial force is exerted in the direction of the dip; and from an analysis of the phenomena of the dip he arrived at the following laws:—

1. That the direction in which the earth's force is exerted, is, at all points upon its surface, in the radial line of its centre.

2. That the vibrations of a horizontal needle being therefore at all points made at right angles to the direction of the force, their number at any two or more stations in similar times, or at different periods in similar times, indicates exactly the ratio of the force at each station and at each period.

On the Development of a Physical Theory of Terrestrial Magnetism, an outline of which was submitted to the Dublin Meeting. By J. Drummond.

The fundamental principle of this theory was the following:—Assuming the prevailing idea regarding the early condition and present state of the globe, viz. that it has cooled down from a state of fluidity, and now consists of a solid crust enclosing a molten nucleus, the author assumed also that the sun, moon, and other planetary bodies must exert the same influence upon the enclosed fluid which they exert upon the surface ocean in producing the tides; that, consequently, a system of internal tides must be occasioned simultaneously with the external tides. Further, accepting the theory of Gauss, that the entire matter of the globe is magnetic, he concluded also that the passage of these internal waves must occasion corresponding changes in the position of the needle; and reasoning from these premises, he arrived at the following conclusions, in regard to the changes in position which the needle ought to undergo. A declination needle at any station resting on the line of the magnetic meridian ought, upon one of the internal waves coming from the eastward, to make an excursion to meet it; as the crest of the wave approaches the station of observation, the needle ought to return with it; and when it comes immediately beneath the point of observation, the needle ought to coincide again with the meridian. As the wave proceeds westward, the needle ought to follow it, making a westerly excursion equal to the easterly; and as the wave passes further west, and its influence over the needle thereby declines, the latter ought slowly to return again to the meridian. Again, an inclination needle ought to begin slowly to dip as the crest of the wave approaches the station of observation, reaching its maximum when the wave is immediately beneath it, and slowly rising again to its former position as the wave passes westward. And the intensity, as indicated by the oscillating needle, ought to increase as the crest of the wave approaches the station, reaching its maximum when it is immediately beneath it, and decreasing gradually as the wave proceeds to the westward, the maximum of intensity thus coinciding with the maximum of inclination. Taking into consideration the conditions under which a system of internal tidal waves must be produced and propagated, the more important of which were pointed out, the author was of opinion that the results of observation fully coincided with this theory.

A Memoir on Electro-Magnetism. By C. L. Draper.

Contributions on the Submarine Telegraph. By Wildman Whitehouse.

On Induced Electrical Discharges taken in Aqueous Vapour. By J. P. Gassiot, *V.P.R.S.*

If the tube of a well-constructed water-hammer is partly covered with two separate coatings of tinfoil, and the coatings are connected, one with the outer, and the other with the inner terminal of an induction coil, a discharge will be observable through the centre of the tube in the form of a wave line. On repeating this experiment, I ascertained that the vacuum in the tube was very much deteriorated. I could no longer produce that peculiar bubbling in the ball of the apparatus which is always attainable by gently heating the tube with the warmth of the hand; this bubbling was originally very sensibly perceptible in the tube I now exhibit when I first received it from the maker, Mr. Casella. I have repeated the experiment with other water-hammers, and always with the same result; but I have not yet opened one to examine whether the vapour has been decomposed, and gas evolved.

At the close of the reading of the paper, the room was darkened, and Mr. Gassiot, assisted by Mr. Ladd, exhibited the experiment.

On the Phosphorescent Appearance of Electrical Discharges in a Vacuum made in Flint and Potash Glass. By J. P. Gassiot, *V.P.R.S.*

The discharge from an induction coil, when taken in a vacuum tube made of flint-glass, has (under certain conditions) the property of rendering the glass highly phosphorescent, the phosphorescence being denoted by the intense blue colour of the glass with which the stratifications are surrounded. On trying the discharge in some vacuum tubes I had obtained from M. Geissler, of Bonn, I observed that the phosphorescence was no longer blue, but was of a slight green colour. To test whether this difference was due to the gaseous matter remaining in Geissler's tubes, or to the character of the glass which he uses, I had Torricellian vacuums prepared in German glass tubes, and in this manner ascertained that the difference in the colour was entirely due to the character of the glass: that of Germany is, I believe, made with potash, and is entirely free from any lead, while in the English flint-glass lead is introduced to some extent. I have recently obtained a vacuum tube from Bonn, which shows this difference in a very beautiful manner: the outer ends of the tube are composed of German glass, the centre of the tube is of English glass; by this arrangement the contrast between the two is very manifest.

Exhibition of Apparatus showing the Correlation of Forces, and Exhibition of Heating Effects, by Mechanical Operations, on a peculiar Form of Antimony. By George Gore.

On an Improved Induction Coil. By W. Ladd, *Chancery Lane.*

Having been rather extensively engaged for the last two years in the manufacture of induction coils, and having received the constant and able advice of Mr. J. P. Gassiot, and the practical suggestions of Mr. C. A. Bentley, I have thought that a brief description of the machine as it is now made, with the results obtained, may not be uninteresting. My object has been not to make very large machines, but to obtain the greatest results from a three-mile coil, that being sufficiently large for all ordinary purposes. I find the best length for the iron core to be 13 inches and about 15·8 diameter, composed of fine iron wire not larger than No. 22, very carefully annealed. The primary wire should be of sufficient size to carry freely the whole of the battery current, and of sufficient quantity to saturate thoroughly the iron core with magnetism. For this purpose I use three layers of one continuous No. 12 copper wire carefully annealed: if more layers are used, I find that the secondary wire is removed too far from the magnetic influence. The secondary wire ought not to be larger than No. 35, covered with silk, which must be laid on perfectly even and insulated from the primary wire, and also from the layers of the secondary next to it. I find the best insulating medium to be the thinnest gutta percha made, and which I believe to be the only gutta percha sold which cannot be adulterated; it is true that it has many minute perforations, but by laying on at least six thicknesses between each layer of wire perfect insulation is secured. The greatest care must be taken in protecting the ends of the layers so as to prevent the sparks passing from one to the other. The condenser should be at least fifty sheets of tinfoil of about 1 square foot in size. These sheets must be separated from each other by three sheets of varnished paper or gutta-percha tissue. Every alternate sheet of foil is conected together, thus forming two poles, to be attached one to each side of the break. It may be placed at the bottom of the stand or in a separate box,—the latter I prefer. In developing the power of the machine, everything depends upon the contact breaker, which should be capable of retaining contact until the whole of the magnetism is obtained, and capable also of breaking contact as soon as the smallest quantity is induced. *These results are obtained in the break attached to this instrument.* The hammer is made to vibrate freely between the iron core and the coil, and the brass screw terminating with the platinum plate at the back of the hammer: a very small amount of magnetism will be sufficient to attract the hammer, and so break the contact. If, now, I bring this screw (placed half-way up the spring carrying the hammer) to bear upon the spring, it will have the effect of pressing the two platinum plates together, so that it takes a greater amount of magnetism to separate them. By this means I can regulate the power of the instrument to the purposes for which it is required. The battery I employ is a five cells of "Grove's," with immersed platinum plates 5×3, having an exposed surface of 140 square inches. With such a battery and a coil thus constructed, I can always ensure sparks from half an inch to 4 inches in air. The machine now exhibited contains six miles of wire, and, worked with the same battery, gives $6\frac{1}{4}$-inch sparks. The position which the induction coil is now taking in this electrical age is one of considerable importance. It has awakened new philosophical ideas, and is being successfully applied to practical purposes of the highest advantage to mankind. For blasting purposes, a three-mile coil is capable of firing fifty charges simultaneously. But important as its present position is, and successful as its past application has been, there can be little doubt that machines can be constructed that will obviate the necessity for employing such ponderous machines, and still more ponderous batteries that have been at work on the Atlantic Cable.

On the Magnetic Dip at Stockholm.
By Dr. F. A. Siljeström, *of Stockholm.*

Later observations on the magnetic dip at Stockholm confirm the known fact that this magnetic element has a minimum in the winter.

Astronomy.

On the Perihelia and Ascending Nodes of the Planets.
By Edward Joshua Cooper, *F.R.S.*

It is known to many that my attention has been called to the distribution, in heliocentric longitude, of the perihelia and ascending nodes of the planets since the year 1850. In 1851, the then results were published by me, in my Preface to 'Cometic Orbits.' Since that period I communicated the further results, arising from subsequent discoveries of asteroids, to the Royal Astronomical Society and the Royal Society. The last notice which I communicated to the Royal Society was in the last year, when the number of known planets was 51. This notice was accompanied by diagrams of their positions. At present there are 62; but no elements of the last have been yet, I believe, computed. Taking, then, 61 of these, we find that the perihelia of 42 are found in the semicircle of heliocentric longitude, between 0° and 180°, and only 19 in the other semicircle. With reference to the ascending nodes of the 60 planets, 42 are likewise found between 0° and 180°, and only 18 in the remaining semicircle. But the accompanying Table will show some more remarkable results, viz. that when there were only 4 known asteroids and 7 large planets, if we add to them Neptune, making 12 in all, the perihelia of 10 of these are found between 0° and 180°; and of the nodes of the 11, none are in the semicircle 180° to 360°. This Table also exhibits these somewhat singular facts, that, adding to the first 12 those subsequently discovered in groups of 10, the number of perihelia and number of ascending nodes in each semicircle are almost exactly similar. I would also observe, that it may be seen, by the diagrams of heliocentric longitude, that the perihelia and ascending nodes are frequently grouped together in a remarkable manner. I deal now entirely with facts: causes I leave to the more learned in celestial dynamics.

Including Neptune from the First.

	L. Ps. 0° to 180°	180° to 360°.
When 12 Planets there were	10	2
22 ditto	17	5
32 ditto	25	7
42 ditto	30	12
52 ditto	37	15
61 ditto	42	19
	☊ 0° to 180°	180° to 360°
When 11 Planets there were	11	0
21 ditto	18	3
31 ditto	25	6
41 ditto	30	11
51 ditto	36	15
60 ditto	42	18.

Donati's *Comet.—Extracts from Letters received by* E. J. Cooper, *M.P.*, *from* Mr. A. Graham, *M.R.I.A.*

"Markree Observatory, Sept. 20.

"I hoped to be able to give you ere now some interesting details of this glorious comet, but I was arrested in my calculations by a curious result in my observation of September 14,—the only really good one which the weather permitted me to make up to that time. Both the compared stars occur in Bessel's zone 359. One of the two is also in Lalande, No. 21775 (Catalogue). The mean right ascensions from the two catalogues differ by 12 seconds in time! There were two wires taken by both observers, and I have carefully looked over the reductions. I even got C. Robertson (second assistant) to ascertain the mean places, and he brought out exactly the same result as I. On Saturday evening (18th) the comet presented rather a striking appearance in the nucleus and coma. The part to the right-hand side of the tail was brighter than the left. I directed the attention of C. Robertson to this circumstance, to make sure that my eyes did not deceive me; and his impression precisely accorded with mine. Now it did not strike me at the time that this was the side next the sun, and that the phenomenon indicated a phase such as would be caused by light reflected from the surface. The appearance of the tail was exactly such as would be presented by a hollow conoid of thin vapour under the circumstances. It will be interesting if other observers confirm this remark."

September 22. "We got satisfactory observations of the comet on Monday and Tuesday nights. The note in the observing book for Monday the 20th is as follows:—The south side of the nucleus faded off gradually into the coma without any defined boundary line. The north and north-east pretty well defined. The nucleus seemed to be stretched out westward at an angle of about 120° with the tail, giving a rough idea of a cusp. There was a similar appearance towards the east, in continuation of the line, but not so well marked. Southward of a line touching the nucleus on the north side, and making an angle of about 60° with the axis of the tail on the east side, the light was decidedly stronger than on the other side of this line. The entire impressed us with some such idea as a view of Venus would give when slightly gibbous, and when seen very near the horizon, with bad definition. The light of the tail was pretty uniform throughout the entire breadth for about twice the diameter of the nucleus northward. Thence it parted into two rays, the upper one being the brighter and broader. The tail was directed precisely to χ Ursæ Majoris, and was about 6° long at least, but the strong moonlight probably obliterated the fainter portion."

Note taken Sept. 21. "Appearance pretty much as last night. The angle made by the line, which I have regarded as the north limit of the phase, with the axis of the tail, is not quite so small as 60°. About 75° is a more correct estimate. The tail was directed almost precisely to Polaris. Moonlight greatly diminished the effect, and took from the apparent length of the tail."

On the Results of the Measures of Gamma Virginis for the Epoch 1858, *as determined by* Admiral Smyth. *By* John Lee, *LL.D., F.R.S.*

I had the honour of presenting to Section A of this Association at Dublin, in 1857, the results of measurements of the double star γ Virginis for the epoch 1857, and I now have the gratification of presenting similar results of the position and distance of this important double star γ Virginis, for its last apparition, as observed at the Hartwell Observatory, with corresponding results obtained at Greenwich by Prof. Airy, at Haddenham by Mr. Dawes, at Tarn Banks, by Mr. Fletcher, and at Wrottesley by My Lord Wrottesley. The discrepancies are certainly greater than might have been expected under the present easy state of the object, but on the whole a very satisfactory epoch is gained. Although stars had been telescopically observed in close juxtaposition as early as the middle of the seventeenth century, the firm settlement of the physical theory of double stars by observation and reasoning was reserved for Sir William Herschel, whose sustained and indefatigable researches from 1779 to 1820 form the broad basis of our present sidereal astronomy. Of the whole of the numerous objects which compose his invaluable contributions to this crucial branch of knowledge, one of the most interesting and momentous is assuredly the star γ Virginis, whose observed and computed places have generally been found to agree within the limits assigned to probable errors of observation. This star now presents a system which affords, by actual changes both in angular velocity and distance—the former varying inversely as the square of the latter, with the elliptical orbital elements deducible therefrom—incontrovertible evidence of the physical connexion of its constituent members. This binary star has been very assiduously watched by various astronomers, especially during the last thirty years; and the obtained results are converting probability into demonstration respecting its being subject to the same dynamical forces which govern our own system. Every advance tends to prove the universality of the Newtonian influence of attraction, obeying the Keplerian law of areas. In a word, by warranting the conclusion of the inconceivable extent of the controlling agency of gravitation, it forms a wonderfully sublime truth in astronomical science.

On a New Variable Star (R. Sagittarii), discovered with the 5-foot Smythian Telescope of the Hartwell House Observatory. By N. Pogson. (*Communicated by* John Lee, *LL.D., F.R.S.*)

On the limit of a rich and widely-spread group of stars, Professor Argelander of Bonn observed one of the 8½ magnitude, in his zone No. 227, on the night of August 7th, 1849. Exactly *seven years* later, while carefully charting in the vicinity, I found the assigned position unoccupied; but entertaining no suspicion of variability, supposed an erratum to exist in the published zone, and simply noted the star as "missing." On July 3rd of the present year, while looking over my chart with the Smythian telescope (quite forgetful of the above-named circumstance), I was struck by finding a fine star nearly of the eighth magnitude not previously recorded; a micrometer was immediately applied and some observations taken with the aid of a sidereal chronometer kindly lent me by the Royal Geographical Society; these however served only to establish its fixity, thereby proving that it was not one of the small planets, but most probably a new variable star. Subsequent comparisons of its brightness with five stars in the same field of view, have since confirmed this conclusion.

The uncertain state of the atmosphere from night to night, and other causes, combine to render mere estimations of magnitude worthless for determining the period of a variable star. It is therefore best to select a number of comparison stars, ranging in magnitude from the maximum brightness of the variable, to the *minimum visibile* of the telescope, and if possible in the same field of view, to assume the mean of several estimations of these comparison stars, made on different nights, as correct, and so to note the difference of magnitude between the variable and such of the comparison stars as most nearly agree with it in brilliancy. By this means small variations which must otherwise escape notice may be satisfactorily detected, and a change amounting to a whole magnitude cannot possibly be overlooked. The following observations of the new variable star were by this means obtained :—

1858,	July 3	8·2 magnitude.	August	1	9·4 magnitude.
	„ 11	8·0 „	„	8	9·6 „
	„ 19	9·0 „	„	31	11·2 „
	„ 29	9·3 „	Sept.	5	11·4 „

Combining these with Professor Argelander's in 1849, and with my own records of invisibility in 1856, it appears most probable that seven maxima occurred between August 7th, 1849, and July 3rd, 1858 ; in which case the period will not differ much from 465 days, and the next maximum will fall due in September or October 1859. It would, however, be premature to state this as anything more than a probable surmise, only to be decided by further observation.

On the Constitution of Comets. By Dr. F. A. Siljeström, *of Stockholm.*

The prevailing opinion about the comets is, I think, that these heavenly bodies are most likely to consist of an infinitely thin gas, or perhaps rather *dust*. I have tried to show the great difficulty of explaining the diaphaneity of the comet, unless the so-called "dust" is composed of more or less considerable masses of some dense (planetary) matter (the comets might be agglomerations of bodies like the metoric stones?). Under this supposition, the diaphaneity of the comets may be experimentally represented by an ordinary rotatory machine (used to show the figure of the earth as being an effect of her rotation), which, if the brass rings have been covered with white paper, will show a globe of feeble white, through which a candle-light may be seen with undiminished intensity. [In this experiment the rotation may be considered only as having the same optical effect as in reality the great distance.]

All the other phenomena, such as the great variation in the light, intensity, the changes of volume, &c., seem to be very easily explained in this hypothesis. As to the *tail* of the comet, I have tried to show that it may be not unsatisfactorily explained by a *ring* (also consisting of the above-named small bodies of dense matter) surrounding the bulk of the comet; and indeed the comet of 1813 presented an appearance almost like an *experimentum crucis* for this hypothesis. However, further observations are necessary to establish *any* theory in this belief.

On the successful establishment, by Astronomer Broun, *of a Meteorological and Magnetical Observatory at Travancore, at* 6200 *feet above the Level of the Sea; with Results of Magnetical Observations at Trevandrum, as communicated in a Letter from* Mr. Broun *to* General Sir Thomas Brisbane. *By* Colonel Sykes, *F.R.S.*

The author,—after giving a graphic account of the wild and difficult country in which Mr. Broun, now Astronomer to the Rajah of Travancore, formerly assistant to Sir T. Brisbane, and the dangers he had to encounter from wild beasts as well as the difficulty of inducing the necessary workmen and labourers to encounter the cold as well as the dangers of these elevated regions, having many nights to sleep exposed to the weather and to heavy rains while the observatory was constructing,—read the following letter :—

"Trevandrum Observatory, July 10.

"My dear Sir,—One of the first results which I obtained from the observations made in your observatory at Makerstoun, was the annual law of variation of the horizontal force of the earth's magnetism; the law, namely, that the force was a maximum near the solstices and a minimum near the equinoxes. This law was communicated by me to the British Association in 1845,—confirmed by a discussion of the Toronto Observations for 1842; it was also confirmed by the results for other years at Makerstoun, in a paper read to the Royal Society of Edinburgh, January 5, 1846. I afterwards further confirmed it by the results of observations made at Munich, by Dr. Lamont, in the years 1843–45. Persons interested in these questions who have examined plate 4 accompanying the paper already cited, must have remarked the symmetrical and well-characterized curves (No. 8), which represent the movement of the daily mean force from the beginning of January till the end of March, 1844. It must have appeared curious that Makerstoun should have been the only place where such curves have been produced, or, at least, that no other place has shown anything resembling them. The exhibition of the annual law depends so much on a permanent magnet, an undisturbed instrument, and well-corrected observations, that it may have seemed less curious that different results for this period should have been obtained. As I was satisfied that the curves referred to were real representatives of the daily variation of force, I was anxious to compare carefully other observations for the purpose of showing to what extent the law was similar at other places. After I had arranged anew the observatory of His Highness the Rajah of Travancore here, and established another on the highest peak of our Ghats, I commenced an examination of the observations made at Trevandrum in 1844 by my predecessor, the late Mr. Caldecott. These observations had never been corrected for temperature, nor indeed had the coefficients been determined; and on my first researches, as the observations did not quite satisfy me, I put them aside. On discussing them carefully, however, about a year ago, having determined the necessary corrections myself, I was much gratified to find that the results at Trevandrum in 1844 agreed perfectly with those at Makerstoun. This fact I announced in the following terms in a letter sent to England in the beginning of this year:—'The relative changes of mean horizontal force are the same all over the globe; and the changes from day to day of the mean horizontal force at different places on the earth's surface are nearly equal, the unit in each case being the whole value of the horizontal force at the place. In other words, the changes of mean horizontal force from day to day are in the same direction all over the globe, and are proportional to the horizontal forces at the places; the different effect of disturbance due to its diurnal period and the different directions of the secular change being allowed for.' It was attempted in this paragraph to give a *general* statement of the result,—I shall attempt here to be somewhat more definite. The chain of observatories of the British Government confirmed and extended the result first due to Celsius and Graham, and afterwards to Arago and Kupffer, that magnetic perturbations are felt simultaneously at places widely distant; but the conclusion did not go beyond this—it appeared that even for moderate disturbances of one element at one place, some element, it might not be the same, showed disturbance at the other place. Having satisfied myself of the great similarity of the variations of force at Trevandrum and Makerstoun, I could have no doubt but the same result would be obtained from moderately good instruments at other places; I accordingly undertook the discussion of observations at Hobarton, Van Diemen's Island, the Cape of Good Hope, and several other places. As I had to obtain the temperature coefficients and to correct the observations by my own processes, the reductions were necessarily laborious. I first corrected the observations at Hobarton, and compared the monthly mean values at the two stations. I found not only that the annual law was the same at the two stations, Makerstoun and Hobarton, but that the changes of the individual monthly means followed *generally* the same law throughout the years 1844, 1845, 1846, 1847, and 1848, though the diurnal series of observations at Makerstoun were incomplete in the last three years. The secular change seems to obey the same law at both stations, but the amount is greater at Hobarton than Makerstoun. This will be seen by comparison of the monthly means in parts of the horizontal force at the respective places for the year 1845:—

1845.	Hobarton.	Makerstoun.	Difference.
January	·002565	·000943	·001622
February	·003023	·001013	·002010
March	·003227	·000988	·002239
April	·003206	·000890	·002316
May	·003593	·001340	·002253
June	·003920	·001645	·002275
July	·003813	·001572	·002241
August	·003737	·001407	·002330
September	·003625	·001078	·002547
October	·003982	·001461	·002521
November	·004312	·001851	·002461
December	·004472	·001895	·002577

An examination of the means given above will show that they follow similar laws at both places, the average variation of the amounts of *difference* from month to month being only about one ten-thousandth ($\frac{1}{10000}$) of the whole force, a change that would be produced by a variation of half a degree Fahrenheit in the temperature of the magnet; and this amount includes the differences due to different secular change and different effect of disturbance. The above numbers, however, are far from giving an idea of the great resemblance in the monthly mean variations at the two places. It will be some evidence of their agreement, that I was enabled, after projecting the mean annual curves for Hobarton and Makerstoun, to point out that two monthly means for Hobarton were probably inaccurate. An examination of the printed observations showed that this was the case—that one monthly mean was erroneously calculated, the other error being probably typographical. The former error was less than two scale divisions, or a quantity which would be produced by a change of 2° Fahr. in the temperature of the magnet. As it was desirable to compare the monthly mean variations more minutely than can be done from the twelve values for each year, I combined the observations in a manner differing somewhat from that hitherto adopted. The usual plan has been, in examining the variation from month to month, to employ only those values corresponding to the middle of the months, or the means of the observations from the first to the last day of each month; and in order to obtain from these, the law of variation, the epochs of maximum and minimum, the means are projected, a curve being passed through or among the points; or the means are considered functions of the line of the sun's longitude and the values for different epochs are calculated. Where merely general results are desired, and where the means for a number of years are combined, either process is sufficient; but neither is satisfactory when we wish to note the changes of force as they exist for short periods. For this purpose, I have obtained the means of the observations made from the 1st to the 28th inclusive, from the 2nd to the 29th, and so on; so that if observations had been made on every day of the week, we should have in this way a monthly mean corresponding for its middle point to each day of each month, each period containing a lunation. The result obtained was as follows:—the monthly mean values of the horizontal force of the earth's magnetism at Makerstoun, Hobarton, Trevandrum, &c., obey the same law,—the *minute* variations of the monthly mean being shown similarly at all the places, but the relative amounts of the changes are sometimes greater at one place, sometimes at another.

I was now led to consider the variations of the *daily* mean magnetic force. In the observations issued from the Colonial observatories, the daily means for each Göttingen astronomical day are given: at Makerstoun and in several other observatories, the civil day of the place has been taken. Both methods have advantages; a disadvantage of the former method is, that as no observations were made on Sundays, some observations made on Saturday had to be combined with some observations on Monday to form one of the six daily means in each week,—so that one daily mean in six was not comparable with the mean of any other place not in the same meridian. It was obvious, however, that for my purpose one daily mean from twenty-four hourly observations was insufficient; it was necessary to obtain a daily mean for *each* hour, as I had obtained a monthly mean for each day. Thus I combined the twenty-four observations from midnight on Sunday till 11 o'clock on Monday night for the first mean of the week, 1 A.M. till 12 P.M. of Monday for the second mean, and so on. In this way 120 daily means were obtained for each week. It was not possible, however, for me to reduce and discuss the observations for a long period in this way; I therefore limited myself, as regards the changes of mean *daily* force, to the six weeks commencing January 28, ending March 9, 1844, to which period belongs one of the most symmetrical curves projected in plate 4 already cited. I performed this discussion for six places included within the latitudes of 42° South and 55° North, and I found that the changes of daily mean force from day to day followed, on the whole, the same law at all the places. The differences and the exaggeration of some of the movements, especially in high latitudes, seem to depend on the different values of the disturbance at different places; but so exactly do the curves in their *general* forms (and frequently in their more minute inflexions) follow each other, that we might, were the curves for each place presented separately, suppose that they were the same curve. The sudden changes, and, indeed, with a few exceptions, all the turning points, occur nearly simultaneously over the globe within the limits considered. There seems to be a period of about two days and a half, or of about sixty hours, for which I can offer no hypothesis. This period is exhibited more markedly sometimes near the equator, sometimes in high north latitudes; but in general Hobarton has the movements slightly smaller than the other stations; but this may depend on the epoch of the year. I can see no connexion between these points and the position either of the sun or moon. I can form no other hypothesis than this, that they exhibit the variations of the intensity of a distant magnet. If we suppose a powerful magnet to act at a distance by induction on a smaller magnet, we might expect that the *law* of distribution of magnetism in the smaller magnet would be unaltered, and that the variation in the force of the inducing magnet would be shown on the induced magnet. If the induced force were small compared with the proper force of the induced magnet, the variation due to induction at any point might be taken as proportional to the force at that point. This conclusion is not far from the result of these discussions. The whole range of the curve of February 1844, may be represented approximately by 11 at Hobarton, 12½ at Trevandrum, 13 at the Cape of Good Hope, and 14 at Makerstoun, the unit in each case being 0·00014 of the whole horizontal force at the place. The values of these forces are approximately, in English units, 4·5, 7·8, 4·5, 3·4. The total forces are approximately 13·6, 8·1, 7·6, 10·5. The comparative values of the range given above cannot be quite accurate; they depend on the unit coefficient of the instruments having been accurately determined, which is by no means certain in most cases. Even on the theory suggested, it should be remembered that the inductive capacity may vary in different parts of the terrestrial magnet. The differences of the mean movements are small, however, when we consider that the law and amount of disturbance vary with the latitude. Indeed, the general agreement of the curves at different places lead one to conclude that the vertical force, and therefore the total force as well as the magnetic dip, obey the same laws. The diurnal variations of the magnetic declination may be supposed due to two opposing forces acting at right angles to the magnetic meridian. From a comparison that I have made between the daily mean values of the magnetic declination at Makerstoun and Hobarton, I conclude that the mean declination also follows similar laws, the north end of the declination magnet moving generally in the same direction at both places. The variations of the daily mean force from hour to hour are felt simultaneously on all meridians, and, as I have said, they appear to be independent of the position of the sun or moon. Within the limits specified, then, we may say that the magnetic intensity of the earth increases as a whole or diminishes as a whole: it does not increase at one place and diminish at another. These results are quite different from those for the variations of hourly mean force. The latter varies with the latitude and the sun's position (longitude and hour-angle). The horizontal force is greatest near the equator shortly before noon; it is least at the same time in high latitudes. If we suppose, then, that the variations of daily mean force are due (for instance) to the varying force of the solar magnet, we must conclude that it acts on the whole terrestrial magnet simultaneously, so that there is an increase or diminution of force everywhere at the same time. This hypothesis, however, will not explain the diurnal variation, and we must suppose that it is produced by a wholly different *mode* of action. I have suggested that these variations are due to the inducing action of the sun shifting the isodynamic lines, the direction of the lines, and of the shift determining the epochs of maximum and minimum. It is, indeed, obvious that the result is equivalent to a movement of these lines; but whether the inducing action is experienced by the earth's surface, or its atmosphere, was not evident. I think I can prove satisfactorily that the diurnal variation is not due to the sun's heating power, whether on the earth's surface or its atmosphere; but that it may be due to the sun's magnetic action on the atmosphere, is, it appears to me, much more probable. I have said in the letter already referred to that the diurnal variation of the magnetic declination is least near the equator where the dipping-needle is parallel to the terrestrial axis,—so I believe it will be found that the diurnal variation of dip and of force is least in mean latitudes, where the dipping-needle is nearly *perpendicular* to the earth's axis.

"I am, &c., JOHN ALLAN BROUN."

SOUND.

On the Mathematical Theory of Sound. By the Rev. S. EARNSHAW.

The author adverted to the circumstance, that the only impediment to the complete development of the mathematical theory of sound has hitherto been the difficulty of integrating the partial differential equation $\left(\frac{dy}{dx}\right)^2 \frac{d^2y}{dt^2}=\mu\frac{d^2y}{dx^2}$. As an approximative mode of surmounting this difficulty, it has been usual to assume $\left(\frac{dy}{dx}\right)^2=1$. But the author suggested that the legitimacy of that step is by no means evident; and that the true test of the allowableness of it is a knowledge of the change which must take place in the constitution of the atmosphere, in order that $\left(\frac{d^2y}{dt^2}\right)=\mu\left(\frac{d^2y}{dx^2}\right)$ may be the *exact* equation of motion. In this way it will be seen whether the physical change, represented by assuming $\left(\frac{dy}{dx}\right)^2=1$, be of such a minute character as to be allowable. From this it was inferred that the equation which represents the properties of sound does not admit of the assumption $\left(\frac{dy}{dx}\right)^2=1$. The reason why this assumption, though analytically allowable, is not allowable in the problem of sound, is that in that assumption quantities are neglected which (in the case of sound) represent essential properties of wave-motion, so that the equation $\frac{d^2y}{dt}=\mu\frac{d^2y}{dx^2}$ is not an approximation, and from it nothing can be inferred but that the assumption $\left(\frac{dy}{dx}\right)^2=1$ is not admissible. The result of this reasoning is, that the equation $y=F(x+at)+f(x-at)$, which has hitherto been the basis of explanation in treatises on Sound, has nothing whatever to do with sound, but represents the motion of a wave in an imaginary elastic medium of a constitution very different from that of the atmosphere and of all known gaseous media. The mathematical theory of sound is consequently put back to its differential equations, beyond which not an inch of ground can be maintained. Till the differential equation is integrated accurately, without assuming $\left(\frac{dy}{dx}\right)^2=1$, no advance can be made, and science remains *without* a mathematical theory of sound. The author then announced that he has succeeded in integrating the differential equation of sound without approximative assumptions; that he has, in fact, obtained its *exact* integral; and in the result has possessed himself of the key to the various properties of sound. Among several other things, it was stated that the exact integral accounts for the great difficulty which experimenters have found in obtaining accordant velocities of sounds,—for the sweetness of musical sounds,—for the rapid decay of violent sounds as they progress,—and proves that the velocity with which a sound is transmitted through the atmosphere depends on the degree of violence with which it was produced, and not (as in light) on the length of the wave; so that sounds of every pitch will travel at the same rate, if their genesis do not differ much in violence; but a violent sound, as the report of fire-arms, will travel sensibly faster than a gentle sound, such as the human voice. This last property the author stated to have caused him much trouble, in consequence of its being directly opposed to the testimony of almost every experimenter. For many affirmed, as the direct result of their observations, and others assumed, that all sounds travel at the same rate. Fortunately, it transpired at the Meeting, that in Captain Parry's Expedition to the North, whilst making experiments on sound, during which it was necessary to fire a cannon at the word of command given by an officer, it was found that the persons stationed at the distance of three miles to mark the arrival of the report of the gun, always heard the report of the gun before they heard the command to fire; thus proving that the sound of the gun's report had outstripped the sound of the officer's voice; and confirming in a remarkable manner the result of the author's mathematical investigations, that the velocity of sound depends in some degree on its intensity.

METEOROLOGY.

On the Formation of Hail, as illustrated by Local Storms. By W. R. BOWDITCH, *B.A.*

With the fourth or fifth flash of lightning fell hailstones which averaged from half an inch to an inch in diameter. These hailstones accompanied every flash, which appeared to come from the zenith to the place where I was standing; but as soon as the storm had passed away so far that the interval between the flash and report was appreciable, the hail either did not reach us, or but a very few hailstones fell mingled with heavy rain. Between the flashes rain only fell: *with the flash* came a volley of hailstones, and gradually a few drops of rain would mingle with the hail, until at length rain only was falling. The transition from *rain* to *hail* was sharp and well-defined; that from *hail* to *rain* very gradual.

The hailstones which fell were of three kinds:—

I. Solid balls of ice having two or three small bubbles, or one larger one containing air.

II. Balls of which from half to two-thirds consisted of solid ice, the remainder being water and air enclosed in a crust of ice.

III. Balls formed of an outer crust of ice containing water and air. In some instances this icy crust was so thin as to be broken by the fall (though all which I examined fell upon straw), while in others it was thicker, and bore considerable pressure before it broke.

In form the hailstones were spheroidal, sensibly bulged at the part corresponding to the equator on a globe, and depressed at the parts corresponding to the two tropics and the arctic and antarctic circles; and in many, if not all, cases slightly elevated at the two poles. My attention was specially directed to this latter point, and although in some instances the elevation (if any) was insufficient to warrant a judgment without measurement, in many no doubt whatever could be entertained, for the polar portion was evidently tending to form a point. It appeared as if the drop had been originally a perfect sphere, which, by rotation on its own axis had become formed as found, and had then suffered congelation. The bulging towards the equator, and the elevation at the poles appeared the complements of the depressions above described.

The regularity and perfection of form of these bodies forbid the notion of gradual accretion in their descent, and put beyond question the fact of their form being due to the action of a natural law upon fluid bodies placed in the same circumstances. It is to be hoped that other observations, or direct experiments, may enable us to ascertain whether this is the normal form of drops of water falling freely and rapidly through air, and afterwards solidified in a vacuum. The author adds some theoretical considerations in explanation of the formation of hail.

Further Evidence of Lunar Influence on Temperature. By J. Park Harrison, *M.A.*

In illustration of the effects of lunar influence, the author adduced proofs of the frequent recurrence of high and low temperatures on the same day of the moon's age, and also at shorter lunar intervals, not only at Greenwich and Dublin, but at Madras, Toronto, and the Cape of Good Hope. He also expressed his belief that the fall in temperature which takes place at full moon, before first quarter, and shortly after last quarter*, is due to the clearing of the atmosphere at those periods, and the higher temperature about the period of new moon and first quarter to a more clouded state of the sky, the effects observed being attributed to the action of terrestrial radiation. In a subsequent communication attention was drawn to the very different degree of heat which the moon's crust attains at first and last quarters; and to the general clearness of the sky at the periods of greatest fall in temperature in the months of January and May.

On the Decrease of Temperature over Elevated Ground. By Professor Hennessy, *F.R.S.*

The author showed that the decrease of temperature in ascending through the atmosphere depended not only on height above the sea-level, but also upon the absolute height above the nearest surface of solid land. As the temperature of the air at any point depends not only on the pressure at that point, but also on the amount of heat which may be transferred thither by circulation and radiation, it must be a function of the several elements upon which these calorific influences depend. It must therefore vary with the distance of the point from heating or cooling surfaces, as well as with its height above the sea. It will also depend upon the time of the day, and even on the season of the year, for the energy of the causes referred to is manifestly subjected to periodical variations depending upon the position of the sun. The *increase* of temperature observed in ascending for short distances above the ground during the night, and even sometimes during the day†, will thus have its anomalous character explained. In this way the decrease of temperature over plains, mountains, and plateaux would be necessarily very different; and we cannot immediately infer the state of the phenomena in the two latter instances from what may exist in the former. Some of the results of observations made on the hills and mountains of Ireland during the Ordnance Survey, as contained in the volume recently published by Col. James, were referred to as illustrations of these general views.

On the Heating of the Atmosphere by Contact with the Earth's Surface. By Professor Hennessy, *F.R.S.*

The temperature of the atmosphere depends principally on the heat which the earth receives from the sun, and on what it loses by radiation. A portion of the solar heat is absorbed in passing through the air, while another portion penetrates to the earth's surface. The ground becomes thus heated, and the lower strata of the atmosphere acquire the greater part of their heat from contact with the warmed surface. It is admitted that the mode in which the air becomes heated by contact with the ground must be a kind of circulation analogous to that seen in the movements of a heated mass of liquid, such as boiling water. When studying the vertical movements of the atmosphere, with reference to which Prof. Hennessy had made a communication to the Association last year, he had been led to consider the connexion between such movements and the influence of the heated ground. In order to study the question experimentally, thermometers were suspended at different heights above the ground, and under different circumstances of exposure to the influence of the sup-

* See Report for 1857, p. 249.
† See Prof. Forbes in Reports of the British Association for 1840, p. 60.

posed currents. Observations were made every minute, and sometimes every half minute, during short intervals, about the middle of the month of May, on days when the sky was clear, and during which there was consequently a great deal of solar radiation. The following are the principal results observed: the mercury in each thermometer rose and fell alternately during intervals varying from about half a minute up to six minutes. The extent of the oscillations was sometimes very considerable in thermometers freely exposed to the air; the mercury sometimes rising or falling nearly three degrees in three minutes. In general the thermometers exhibited fluctuations of temperature, the intensity of which diminished the more they were protected from the influence of circulating currents in the air. The greatest fluctuations were presented by thermometers with blackened bulbs exposed in the sun. This arose from the circumstance that the blackened bulbs, by acquiring a high temperature, became themselves disturbing agents in the calorific conditions of the surrounding air. Evidence of similar phenomena appears to be presented by the curves of temperature obtained by the aid of photographical registration at the Radcliffe Observatory in Oxford. The application of photography to the continuous registration of atmospherical conditions, has been carried out in that Observatory with so much care, and has been attended with such remarkable success, as to have already allowed its able director to deduce results of considerable interest in meteorology. Among these are results, which observations made merely at stated hours would probably never have disclosed*. Attention has been called by Mr. Johnson to a remarkable serration in the temperature curves during the day. This serration is found only when there is a considerable amount of solar radiation; it disappears during sunless and cloudy weather. While it is explained by referring it to the influence of the solar heat upon the ground, and the consequent circulation of small atmospheric currents, it affords a very satisfactory confirmation of the trustworthiness of the photographical method of registration.

The following Table presents a specimen of the observations made on May 11 with two thermometers, one of which (*a*) had its bulb plunged 0·25 inch below the open mouth of a bell-glass, and the other (*b*) was freely suspended in the air.

MAY 11.

Time.	(*a*).	Diff.	Fluctuation.	(*b*).	Diff.	Fluctuation.
h m	°	°		°	°	°
2 52	66·2	+0·8		62·6	+1·2	
2 53	67·0	+0·2	+1·6	63·8	+0·7	+2·4
2 54	67·2	+0·6		64·5	+0·5	
2 55	67·8	−0·1	−0·1	65·0	−0·2	−0·2
2 56	67·7	+0·3		64·8	+0·2	
2 57	68·0	+0·1	+0·5	65·0	+0·5	+1·2
2 58	68·4	0·0		65·5	+0·1	
2 59	68·4	+0·1		65·6	+0·4	
3 0	68·5	−0·5	−0·5	66·0	−0·6	−0·6
3 1	68·0	+0·2	+0·2	65·4	+0·1	+0·1
3 2	68·2	0·0		65·5	−0·1	−0·8
3 3	68·2	−0·9	−1·0	65·4	−0·6	
3 4	67·3	−0·1		64·8	+0·2	+0·2
3 5	67·2			65·0		

On plunging the bulb of (*a*) more deeply, the amplitude of its fluctuations progressively diminished, and they ceased almost entirely when the bulb was 14 inches below the edge of the bell-glass.

* See Report of the British Association for 1855, Trans. Sect. p. 40. See also Introduction to the Meteorological Observations made at the Radcliffe Observatory in the year 1857, p. xxxiv.

Note on Refraction. *By* Colonel James, *F.R.S.*

Colonel James, Director of the Ordnance Survey, referred to the results obtained in the course of the trigonometrical operations of the survey. It was found that the refraction of the atmosphere was very great in the morning, that it diminished towards the middle of the day, and then again gradually increased towards evening; this he attributes to the greater amount of aqueous vapour in the lower portion of the atmosphere in the morning and evening, as compared with the amount in the middle of the day.

On the Daily Comparison of an Aneroid Barometer with a Board of Trade Barometer by Captains of Ships at Sea. *By* Dr. Lee.

The author submitted tables of considerable length detailing the results that had been obtained during a voyage from London to Madras and back again, and the conclusions he made were as follow:—That aneroid barometers, if often compared with good mercurial columns, were similar in their indications, and valuable; but at the same time it ought to be remembered that they were not independent instruments; that they were set originally by a barometer; required adjustment occasionally; and might deteriorate in time, though slowly. The aneroid was quick in showing the variation of atmospheric pressure, and to the navigator (who knew at times the difficulty of using barometers) this instrument was a great boon, for it could be placed anywhere out of harm's way, and was not affected by the ship's motion, although faithfully giving indication of increased or diminished pressure of air. The aneroid, which is exhibited, had been carefully and daily observed by Captain Toynbee, of the 'Gloriana,' during his recent voyage to Madras.

On the Construction of a Portable Self-registering Anemometer for recording the direction and amount of Horizontal Motion of the Air. *By* F. Osler, *F.R.S.*

In this instrument the direction of the wind is obtained by fans, similar in principle to those at the back of a windmill, as in some anemometers now in use, and the horizontal motion by Dr. Robinson's revolving hemispherical cups. The mode of registration, however, is such as to enable the instrument to be constructed much more compactly than heretofore. The direction of the wind is recorded by means of three pencils inserted in an endless band, or flat chain working over two pulleys of equal size, one of which is on the same shaft as the vane, and revolves with it; the distance between the centres of the pulleys, and also between the pencils, being equal to the circumference of one pulley, that is to one revolution of the vane. By this arrangement one of the three pencils is always making its record on a small horizontal cylinder, over which passes a long band of metallic paper about 5 inches wide. The cylinder, being connected with the shaft turned by the revolving cups, moves at a rate proportionate to the velocity of the air. Stationary pencils rule lines on the paper as it is wound forwards by the motion of the air, and indicate the cardinal points. Upon the margin of the paper, a pencil moved by means of a clock records the time, the quantity of paper worked off in any given time showing the amount of horizontal motion of the air during that period. The instrument can be supplied with a single length of paper sufficient to last for several weeks, and this paper being what is termed metallic, small brass wires slightly rounded at the end are used as pencils. The whole of the registering portion of the instrument is contained in a cylindrical case about 10 inches in diameter, which protects it from the weather, so that it does not require the erection or alteration of a building to carry it, but can be placed for action in any situation that may be desired.

Meteorological Observations at Huggate for 1857. *By the* Rev. T. Rankin.

The first part of the present communication consisted of tables, showing for each month—1. the thermometer; 2. the barometer; 3. winds; 4. weather; 5. rain; 6. hygrometer. Secondly, observations on remarkable days, and circumstances connected with the thermometer, barometer, hygrometer, rain, November atmospheric wave, remarkable appearance of the planet Venus, auroral phenomena, solar halos, a remarkable appearance of the Via Lactea, lunar circles and halos, winds, weather, and thunder-storms.

Note on Observations of Temperature. *By* Dr. F. A. Siljeström, *of Stockholm.*

In a discussion of thirty years' meteorological observations at the Observatory of Stockholm, I have pleaded the necessity of taking meteorological media for *shorter* periods than a month, which latter seems to me to be quite unfit as a meteorological period. I have divided the year in seventy-two parts, viz. each month in six parts of five days (except the last part of the month, whose length varies between five and six days, and for February between three and four). By this means I have not only been able to ascertain quite decided laws in the yearly movement of the temperature, which never could have been detected by monthly means (for instance, three very well-defined minima during the winter, a quite remarkable sinking of the temperature in the beginning of May, &c.), but also to show the intimate connexion between the changes of wind and temperature, and to find, in a somewhat new manner, a confirmation of Dove's celebrated "Drehungsgeschichte." But it is impossible here to enter into further details.

On the Desirableness of renewing Balloon Ascents in England for Meteorological Objects. *By* Colonel Sykes, *F.R.S.*

With reference to the desirableness of renewing the balloon ascents, I shall limit myself to a very few words. The Section is aware that in 1852 the Kew Committee of the British Association effected four ascents. The observers who fearlessly went up in the balloons, were Mr. Welsh, Mr. Nicklin, and the veteran aëronaut Mr. Green. The results of the observations were published in the 'Philosophical Transactions;' and Mr. Petermann, in the 'Mittheilungen,' has given a coloured diagram, from which, by a *coup d'œil,* the accordances or discordances in the results of the four ascents at the different heights at which the same temperature occurred, are seen. 55° and 32° are sufficiently marked. The four ascents took place from Vauxhall Gardens, near London. The temperature of 55° on the different days was met with at 6800, 3900, and 950 feet respectively. At the fourth ascent, on the 10th of November, the temperature at the surface of the earth was below 55°. The freezing-point in the two ascents in August, occurred at 13,200 feet; on the 21st of October, at 10,900 feet; and on the 10th of November, at 8500 feet. Now these differences may be owing to the different angles of the sun on the respective days of observation, and it would not be prudent to consider the indications as normal conditions. Again, the rapid diminution of temperature in the upper portion of the ascents leads to the inference of an almost inconceivably low temperature at the surface of the earth's atmosphere. It was found, also, that the tension of vapour, which at the surface of the earth was very considerable, at nearly 23,000 feet was scarcely appreciable.

All meteorological investigations require so many repetitions to ensure trustworthy results, that I cannot believe that the Mathematical Section will consider investigations into the conditions of the upper strata of the atmosphere exceptional. I trust, therefore, that I only anticipate the wishes of the Section, when I express a hope that it will recommend to the General Committee to cause another series of balloon ascents to be undertaken.

On a New Construction of Standard Portable Mountain Barometers. *By* G. J. Symons.

The author showed an instrument, which was very portable, easily set up, and when packed, only 4½lbs. weight.

Particulars of an Ascent of Mont Blanc. *By* Professor Tyndall, *F.R.S.*

The author spoke particularly of the enthusiasm of a guide named Balmat in the cause of science, and of the efforts that that person had already made towards the advancement of it. He also referred to the fact, that the professional guides, headed by their chief, sought to prevent his going without the usual complement of guides, making no allowance whatever for the circumstance that he was engaged in purely scientific pursuits. This man (Balmat) had conceived the idea of placing on the top of Mont Blanc a thermometer, for the purpose of noting the minimum winter temperature that might occur at that altitude, and the author had been instrumental in obtaining £15 from the Royal Society for the prosecution of that object. But this man was of so independent a nature that he would accept no gratuity, and the result was, that after paying £10 for necessary expenses, the remainder was to be returned to the Royal Society.

The author gave in detail the difficulties he had to overcome in ascending Mont Blanc. He said that the snow, which at that height was like dry dust, was wafted on that day by the wind, and came in great force against the party on the summit. The temperature was 20° below the freezing-point, and the effect was that the eye-lashes and beards of the party were covered by long ice-crystals. In this ascent Balmat's hands had been frostbitten, and up to this time they had not recovered their natural functions.

He then remarked on the obstructions that were encountered by scientific men making observations at Mont Blanc, on account of the arbitrary proceedings of the local authorities. A remonstrance was, however, in process of being drawn up, and he hoped it would have due weight with the Sardinian Government. The guide Balmat was now being prosecuted by the chief guide, on account of his not having acted in accordance with the unreasonable interpretation which the chief guide put upon the printed instructions, and it behoved the Association to render him every assistance for the sake of science.

On a fresh Form of Crystallization which takes place in the Particles of Fallen Snow under Intense Cold. By J. WOLLEY, *M.A.*

In passing a winter in Lapland, it is impossible, whether in observing the tracks of animals, or merely considering day by day the condition of the roads for sledging, or of the snow for the use of snow-skates, not to be struck by the very variable character of the snow, partly caused by winds and fresh falls, partly by the condition of the rime or hoar frost upon the surface, but mainly, as it is soon found, by an alteration in the character of the mass of fallen snow.

In Lapland, as elsewhere, the snow as it falls is of several kinds. But whatever its character, it at first lies more or less lightly on the ground, and if the weather is still and not very cold, it may so remain for days; but if the cold increases, the snow rapidly sinks; it becomes at first like sand, is crisp to the tread, bears the smaller animals, and soon becomes suitable for the skidor or snow-skates. When the cold has continued, probably many degrees below zero of Fahrenheit, for two or three weeks, not necessarily consecutive (the phenomena are more especially to be observed in the cold months of January and February), the snow beneath the surface is found to be made up of large pieces of a quarter or a third of an inch in diameter, glittering in the sunshine, clear, heavy, highly moveable upon one another, and seen upon even a hasty examination to be of a beautiful crystalline structure. On a closer inspection, they are found to be somewhat irregular in shape, with the outline of more or less complete hexagons with sides of unequal length; they are formed around nuclei by no means placed centrally, often quite where one side of the hexagon should be; and they grow in layers of bars one outside the other, often larger in section as well as longer as they recede from the nucleus; these bars (learned gentlemen will excuse me for not describing a crystal more properly) are free from one another except at the angles; those of each layer lie in one plane, often not the same as the layer which preceded them lies in. At the angles are usually small crystalline projections, rising apparently perpendicular to the general surface of the crystal. These crystals are broken with a slight force; and many of those where the snow has been crushed have lost their nuclear portion, but retain the true hexagonal form.

Snow, in the condition of which I hope to have given at least some faint notion, is called *hieta lumi*, or sand-snow, in the Finnish language. It yields more water; and hence, even when it is covered by more recent snow, the Laps take the trouble of digging down to it to fill their kettles with. These primitive people also use it in its dry state for washing or cleansing their clothes. After first exposing to the external cold for some hours the dresses they wish to purify, for reasons which I need not further explain, they beat them with sticks upon and under a heap of sand-snow.

When the winter covering of the ground is in this sandy condition (perhaps the moveable state of such shell-sand as that of John o'Groat's house may best represent it in one respect, and the appearance of a bag of clean crystals of salt give some idea of it in another), it is a great advantage to all the animals of the country in supporting their weight, and is a special comfort to the reindeer, from the facility with which they can remove it with their fore-feet so as to get at their food beneath. Though intensely cold to a naked hand, it is much better than fresh snow for lying upon, as it does not yield too much to the weight of the body, and does not get into the nicks of the clothes, or melt in the fur. I may mention, that with only a thick pair of stockings on, one can walk for some little distance from a bivouac without risk of getting either wet or cold in the feet; and before a fire in the woods this snow never becomes sloppy, but seems to disappear only by evaporation, which greatly adds to the facilities of passing the long winter nights in a Lapland forest. The same thing is in a great measure true in the spring; the snow is very rarely to be found in that miserable state which marks the breaking up of a snow in England.

Concerning the formation of these crystals, I made experiments by burying in the snow at certain intervals of time, chip boxes, some empty and some containing fresh snow: I was prevented from fully carrying out and registering my observations, but I found that the changes went on in the boxes equally with the external snow, and in the boxes that contained nothing but air, but nevertheless were not so tightly closed as to prevent the transmission of air containing water in solution, crystals attaching themselves to the sides and top, but never to the floor of the box, which crystals greatly resembled those in the snow; they were, however, often much longer, even to upwards of half an inch in length. In the course of my observations, I found that this sand-snow formed principally in open places, on lakes, bare soils, &c., growing less on spongy grounds, scarcely at all upon logs of wood or outbuildings.

Instruments.

On Dials which give the Latitude, the line of North and South, and Chronometer Time. By WARRAND CARLILE.

Working models were exhibited. By one model the latitude is read off at once without calculating, and the true line of north and south obtained without a mariner's compass. With the assistance of the compass, the latitude at sea could be read off at any hour when the sun shines. The other model gives true chronometer time, and could easily be constructed to give Greenwich time at any place.

CHEMISTRY.

Address by Sir J. F. W. HERSCHEL, *Bart., President of the Section.*

THOUGH it is with much satisfaction that I find myself placed in the Chair of this Section, it is a feeling not untempered with serious misgivings. On none of the occasions when I have attended the Meetings of the British Association, has it ever been in my power to be present at any Session of the Chemical Section; and attached as I have always been to that branch of science, and contemplating with the most lively sympathy the labours of its more active members, this has been to me a source of great regret and disappointment. And now when the opportunity I have always so earnestly desired is accorded me in its fullest extent, it comes accompanied with the painful feeling of occupying a position, which probably not one of the distinguished cultivators of the science whom I see around me, would not be more competent to fill with credit to himself and satisfaction to the Section. However, in this respect, I must throw myself on your indulgence. If there be any conventional usages in the conduct of the business of the Section, which have grown up as matters of habitual arrangement, and been ascertained by experience to facilitate its working, with which I am unacquainted, there are those around me who will good-naturedly set me right.

But there is one deficiency which I feel very much:—it is the want of that thorough acquaintance, that sort of *coup d'œil* extending over the whole area of the vast field of chemical, mineralogical, and agricultural research which the objects of this Section embrace, which would justify me in the ambitious hope that I could command your attention as I am aware that my predecessors in this Chair have done on some former occasions, while placing before you a summary of the progress made since our last meeting, in these branches of knowledge, and delineating the leading features of their present, and the prospects of their future state. In this I should be sure to fail, and therefore I shall not attempt it, though I cannot help giving expression to my surprise and admiration of the astonishing developments which they have undergone, I will not say since the time when my own acquaintance with chemistry commenced by hanging in rapt enthusiasm over Macquer's Dictionary (which seemed to me in those early days a work of little short of superhuman intelligence); nor since the epoch when a Davy electrified the world by the decomposition of the alkalies; nor that when a Faraday commenced his magnificent career of discovery; nor when a Berzelius first showed what might be done in giving precision to analysis—but since *organic chemistry* has assumed, by the experiments and reasonings of Dumas, Liebig, Hofmann, and its other distinguished cultivators, that highly abstract and intellectual form, under which it now presents itself, and which, by the links of the platina bases, and compounds such as those described by Gibbs and Genth under the name of the ammonio-cobaltic bases, and by those which are every day coming into view by the mutual interweaving, if I may use such an expression, of the organic and inorganic systems of composition in bases such as those of the metallic ethyls and those of boron and silicon—seems to place these conceptions in much the same sort of relation to the ordinary atomic theory as put forth by Dalton and Higgins, and the elementary notions of oxide, acid, and base of Lavoisier, that the transcendental analysis holds to common algebra.

And here perhaps I may be tolerated if I put in a word of reclamation against the system of notation into which chemists, who are not always algebraists, have fallen in expressing their atomic formulæ. These formulæ have been gradually taking on a character more and more repulsive to the algebraical eye. There is a principle which I think ought to be borne in mind in framing the conventional notations as well as nomenclatures of every science, at every new step in its progress, viz. that as sciences do not stand alone, but exist in mutual relation to each other,—as it is for their common interest that there should exist among them a system of free communication on their frontier points,—the language they use and the signs they employ should be framed in such a way as at least not to contradict each other. As the atomic formulæ used by the chemist are not merely symbolic of the mode in which atoms are grouped, but are intended also to express numerical relations indicative of the aggregate weights of the several atoms in each group and the several groups in each compound, it is distressing to the algebraist to find that he cannot interpret a chemical formula (I mean in its numerical application) according to the received rules of arithmetical computation.

In a paper which I published a long time ago on the Hyposulphites, I was particularly careful to use a mode of notation which, while perfectly clear in its chemical sense, and fully expressing the relations of the groupings I allude to, accommodated itself at the same time perfectly well to numerical computation, no symbol being in any case juxtaposed, or in any way intercombined with another, so as to violate the strict algebraical meaning of the formula. This system seemed for a while likely to be generally adopted; but it has been more and more departed from, and I think with a manifest corresponding departure from intelligibility. The time is perhaps not so very far distant, when, from a knowledge of the family to which a chemical element belongs, and its order in that family, we may be able to predict with confidence the system of groups into which it is capable of entering, and the part it will play in the combination. A great step in this direction seems to me to have been lately made by Prof. Cooke, of the Harvard University of the United States (in a memoir which forms part of the fifth volume of the Memoirs of the American Academy of Arts and Sciences), to extend and carry out the classification of chemical elements into families of the kind I allude to, in a system of grouping, in which the first idea, or rather the first germ of the idea, may be traced to a remark made by M. Dumas, in one of his reports to this Association, and which is founded on the principle of arranging them in a series, in each of which the atomic weight of the elements it comprises are found among the terms of an arithmetical progression, the common difference of which in the several series are three, four, five, six, eight, and nine times the atomic weight of hydrogen respectively. So arranged, they form six groups, which are fairly entitled to be considered natural families, each group having common properties in the highest degree characteristic; and what is more remarkable, the initial member in each group possessing in every case the characteristic property of the group in its most eminent degree, while the others exhibit that property in a less and less degree, according to their rank in the progression, or according to the increased numerical value of the atomic equivalent. Generally speaking, I am a little slow to give full credence to numerical generalizations of this sort, because we are apt to find their authors either taking some liberties with the numbers themselves, or demanding a wider margin of error in the application of their principles, than the precision of the experimental data renders it possible to accord; so that the result is more or less wanting in that close appliance to nature which makes all the difference between a loose analogy and a physical law; but in this instance it certainly does appear that the groups so arising not only do correspond remarkably well in their theoretical numbers with those which the best authorities assign to their elements, but that it really would be difficult to distinguish the elements themselves into more distinctly characteristic classes by a consideration of their qualities alone, without reference to their atomic numbers.

When we find, for instance, that the principle affords us such family groups as oxygen, fluorine, chlorine, bromine, and iodine self-arranged in that very order; or again, nitrogen, phosphorus, arsenic, antimony, and bismuth,—when we find that it packs together in one group all the more active and soluble electro-positive elements, hydrogen, lithium, sodium, and potassium, and in another the more inert and less soluble ones, calcium, strontium, barium, and lead, and *that* without outraging any other system of relations,—it certainly does seem that we have here something very like a valid generalization; and I shall be very glad to learn in the course of any discussions which may arise on such matters as may be brought before us in the regular conduct of our business from those more competent to judge than myself, whether I have been forming an overweening estimate of the value and importance of such generalizations. I will only add on this point, in reference to what fell from our excellent President in his address to the assembled Association last night, that this kind of speculation followed out, would seem to me likely to terminate in a point very far from that which would regard all the members of each of these family groups as allotropes of one fundamental one, inasmuch as the common difference of the several progressions which their atomic weights go to make up, are neither equal to, nor in all cases commensurate with the first terms of these progressions. For instance, in the chlorine group, the first term being eight, the common difference is nine. Something very different from allotropism is surely suggested by such a relation. It would rather seem to point to a dilution of energy of one primary element by the superaddition of dose after dose of some other modifying element; and this the more strikingly, since we find oxygen standing at the head of very distinct groups having very striking correspondences in some respects, and very striking differences in others.

But all these speculations take for granted a principle, with which I must confess I think chemists have allowed themselves to be far too easily satisfied, viz. that all the atomic numbers are multiples of that of hydrogen. Not until these numbers are determined with a precision approaching that of the elements of the planetary orbits,—a precision which can leave no possible question of a tenth or a hundredth of a per cent., and in the presence of which such errors as are at present regarded as tolerable in the atomic numbers of even the best determined elements shall be considered utterly inadmissible,—I think, can this question be settled; and when such gigantic consequences,—so entire a system of nature is to be based on a principle,—nothing short of such evidence ought, I think, to be held conclusive, however seductive the theory may appear. I do not think such precision unattainable, and I think I perceive a way in which it might be attained, but one that would involve an expenditure of time, labour, and money, such as no private individual could bestow on it.

If the phenomena of chemistry are ever destined to be reduced under the dominion of mathematical analysis, it will, no doubt, be by a very circuitous and intricate route, and in which at present we see no glimpse of light. We should, therefore, be all the more carefully on the watch in making the most of those classes of facts, which seem to place us, not indeed within view of daylight, but at what seems an opening that may possibly lead to it. Such are those in which the agency of light is concerned in modifying or subverting the ordinary affinities of material elements, those to which the name of actino-chemistry has been affixed. Hitherto the more attractive applications of photography have had too much the effect of distracting the attention from the purely chemical questions which it raises; but the more we consider them in the abstract, the more strongly they force themselves on our notice; and I look forward to their occupying a much larger space in the domain of chemical inquiry than is the case at present. That light consists in the undulations of an etherial medium, or at all events agrees better in the characters of its phenomena with such undulations, than with any other kind of motion which it has yet been possible to imagine, is a proposition on which I suppose the minds of physicists are pretty well made up. The recent researches of Prof. Thomson and Mr. Joule, moreover, have gone a great way towards bringing into vogue, if not yet fully into acceptation, the doctrine of a more or less analogous conception of heat. When we consider now the marked influence which the different calorific states of bodies have on their affinities—the change of crystalline form effected in some by a change in temperature,—the allotropic states taken on by some on exposure to heat,—or the heat given out by others on their restoration from the allotropic to the ordinary form (for though I am aware that Mr. Gore considers his electro-deposited antimony to be a compound, I cannot help fancying that at all events the state in which the antimony exists in it is an allotropic one),—when, I say, we consider these facts in which heat is concerned, and compare them with the facts of photography, with the ozonization of oxygen by the chemical rays of the electric spark, and with the striking alterations in the chemical habitudes of bodies pointed out by Draper, Hunt, and Becquerel; and when, again, we find these carried so far, that, as in the experiments of Bunsen and Roscoe, the amount of chemical action numerically measures the quantity of light absorbed,—it seems hardly possible not to indulge a hope that the pursuit of these strange phenomena may by degrees conduct us to a mechanical theory of chemical action itself. Even should this hope remain unrealized, the field itself is too wide to remain unexplored; and to say nothing of discovery, the use of photography merely as a chemical test may prove very valuable, as I have myself quite recently experienced, in the evidence it has afforded me of the presence in certain solutions of a peculiar metal having many of the characters of arsenic, but differing from it in others, and strikingly contrasted with it in its powerful photographic qualities, which are of singular intensity, surpassing iodine, and almost equalling bromine.

There is another class of phenomena, which, though usually considered as belonging peculiarly to the domain of general physics, and so out of our department, seems to me to want some attention in a chemical point of view;—it is that of capillary attraction. The coefficient of capillarity differs very remarkably in different liquids, and no doubt also in their contacts with different solids;—a fact, which can hardly be separated from the idea of some community of nature between the capillary force and those of elective attraction. I hardly dare to hint at the existence of some slight misgiving I have always felt as to the validity of the received statical theory of capillary action, which carries with it the authority of such names as those of Laplace and Poisson. Any discussion of this point would be matter for another Section of this Association; and if I here touch upon it, it is only to observe that my impression of the requisiteness of a force *so far allied to chemical affinity as to be capable of saturation*, rests on other grounds besides that of the mere diversity of action above alluded to. But I must remember that you are not met here to listen to generalities, of whatever nature, but that we have plenty of real and special business before us.

In the several papers which will be brought before this Section,—in the elucidation their authors will personally afford, and in the discussions which will take place on them,—I look forward to rich accessions to our knowledge, and to pregnant and fertile suggestions which will afford us matter of fruitful meditation hereafter; and I am very sure, that in the course of such discussion as may involve differences of opinion, that spirit of mutual and amicable concession which has always characterized the meetings of this Section will continue to prevail.

On Colorific Lichens. By J. Bedford.

The lichens specially referred to were those used in the manufacture of orchil and cudbear. The author stated that prior to the year 1838, all the lichens employed were such as grow upon rocks only. In that year, however, a new kind of lichen was introduced from Angola on the west coast of Africa, by Mr. F. R. Batalho, a Lisbon merchant, to whom much credit is due for the discovery of its properties and uses. The novelty consisted in its being a tree lichen, as previously all such had been found useless for this manufacture.

In 1839 another tree lichen, possessing valuable colouring properties, was discovered by Mr. G. C. Bruce in Ecuador, South America, and brought into the market in 1840, under the name of Lima Weed.

Similar lichens are now imported from Loango, Benguela, Mozambique, and Madagascar, several of which are considered to be of equal or even of more value than the best quality of rock lichens. The result has been to reduce the market price of orchil weed from about £300 to £50 per ton; and now tree lichens form something like four-fifths of the total quantity consumed in the manufacture.

The author exhibited illustrative specimens of rock lichens from the Canary and Cape de Verde Islands; also from Madeira, the Azores, and Sweden, together with the tree lichens from the places above-mentioned.

On the peculiar action of Mud and Water on Glass, as more especially illustrated by some Specimens of Glass found in the Lake at Walton Hall, near Wakefield, the residence of Charles Waterton, Esq. *By* C. W. Bingley, *Ph.D., F.C.S.*

Along with several other articles lately found in the lake at Walton Hall, near Wakefield, the residence of Charles Waterton, Esq., were some specimens of glass, supposed to have been submerged in the lake ever since the hall was attacked by Oliver Cromwell's soldiers.

The interest those specimens possessed in a scientific point of view consisted in the remarkable appearance they presented after their submersion, possessing hues of colour rivalling those of the finest specimens of pearl shells. Some of the specimens are of a beautiful azure blue by direct light, and yellow by transmitted light; others of a fine green colour by reflected light, and red and pink by transmitted light; whilst others again are of a red and deep orange colour by reflected light, and blue by transmitted light.

On scraping the glass with a penknife, the coloured part was detached in minute scales, those exhibiting the red and orange rays of colour coming off easily, when green and bluish scales became disclosed to view, which were with more difficulty removed. The glass underneath appeared as if it had been ground, or subjected to the action of hydrofluoric acid. On analysis, the scales were found to consist of silicates of lime associated with iron, but no potash or soda; whereas the glass consisted of a silicate of potash, with a very slight trace of lime and iron. The glass appeared, therefore, to be an alkaline silicate, and much more fusible and more easily acted upon by disintegrating agents than the glass now manufactured. The potash originally in it appeared, in the case of the detached scales, to have been replaced by lime and iron derived from the water. The mud in which they had been imbedded was found on analysis to contain a large quantity of organic matter, containing nitrogen, and water charged with sulphuretted hydrogen. No sulphur was found in any form, either in the glass or in the scales. Any hypothesis, then, of the colours observed owing their origin to the combination of sulphur with the bases in the glass, the author observed, was perfectly untenable.

It has been known for a long time that water acts more or less upon glass, slowly decomposing it. Scheele, for example, observed that distilled water, which had been boiled a long time in glass vessels, became alkaline. Ebelmen published some time ago an account of the strong action of water charged with carbonic acid on glass. Mr. H. C. Sorby had lately shown the author some specimens of glass which had rapidly undergone partial devitrification during their exposure to the action of water boiling under pressure, at a temperature exceeding 300° C. The action of water on glass is materially assisted by the presence of ammonia. Glass in stable windows is frequently corroded from this cause. The disintegration of the glass found in the lake at Walton Hall appeared to the author to have arisen from the combined action of the water and the ammoniacal and carbonic acid gases derived from the mud, assisted by the pressure resulting from the superincumbent water. It is probable that the transformation of the glass was produced by the silica of the glass, after the separation of the alkali, being left in a gelatinous state, entering into combination with lime, derived from the mud or water of the lake, to form the insoluble silicate of which the scales were composed, analogous in composition to tabular spar.

The author next proceeded to a consideration of the peculiar colour of the glass. On fusing the glass, after removing the scales, it was perfectly colourless. The detached scales, which were very difficult to fuse, likewise became colourless. The coloured glass, viewed by transmitted light, exhibited rays of colour complementary to the reflected rays. The various colours presented, therefore, doubtless owed their origin to the different refractive powers of each of the scales; the refractive powers of the latter again depending on their thickness.

On the Expansion of Metals, Alloys, and Salts. *By* F. CRACE CALVERT, *F.C.S.*

Messrs. Calvert and R. Johnson having purified a considerable number of metal for the purpose of ascertaining some of their properties, were desirous of testing their expansion and contraction when exposed to certain temperatures. The apparatus employed in making these experiments is one constructed by Mr. G. C. Lowe. It consists of a lever with a long and a short arm. The short arm is brought to bear upon the bar to be tested, and in the end of the long arm the object-glass of a telescope is inserted. An eyepiece of considerable magnifying power is so fixed, that an observer, by looking through it, at a graduated scale, is able to determine with the greatest accuracy the distances through which the object-glass is displaced when heat is applied to the bar. The parts of the apparatus are so adjusted that $\frac{1}{50,000}$dth part of an inch expansion is represented by a definite portion of the graduated scale.

In the course of these experiments it was found that marked differences were observed between the results obtained and those of previous experimenters. This was attributed to the circumstance of the metals they were employing being in a pure state, and this view was confirmed by trying in the same manner metals of ordinary commercial quality. They observed also that a change of the molecular condition of a bar produced a considerable change in its ratio of expansion. Thus a bar of steel, when tempered to an extreme hardness, has a ratio of expansion fully one-third greater than when it is left soft from the fire; and most of the metals have a very different ratio according as they are cast or forged. This is particularly remarkable in the case of pure zinc, a bar of which, when well-hammered, expands very little more than half the amount that it expands when cast vertically. Again, the axis of crystallization has a considerable influence upon the expansion of bodies. A bar of pure zinc cast horizontally expands much less than if cast vertically. A similar phenomenon was observed also in examining other crystalline bodies. Thus amongst the carbonates of lime, statuary marble was observed to expand more than some of the metals, amongst which are cast iron, antimony, and platinum; whilst the expansion of chalk, in which the particles are differently arranged, is little more than one-fourth that of marble. In several alloys of metals a remarkable difference was observed between the expansion found by experiment and that calculated from by the ratios of the metals of which they were composed. Four different alloys were made and examined, and in each the expansion observed was less than that deduced by calculation from their equivalents. In alloys of copper with tin, it was found that where only a small quantity of tin entered into the composition of a bar, the expansion fell considerably below that of pure copper, although the tin thus added has a much higher ratio of expansion than copper.

The following is one of the Tables accompanying the paper.

Coefficient of Expansion from 0° to 100°.

Cadmium	0·003323	Copper (hammered)	0·001769
Lead	0·003005	Gold (do.)	0·001374
Tin	0·002717	Bismuth (do.)	0·001341
Aluminium	0·002218	Iron (forged)	0·001187
Zinc (hammered)	0·002193	Cast iron	0·001117
Silver (cast)	0·001991	Steel (hard)	0·001402
Brass (do.)	0·001930	Steel (soft)	0·001038
Copper (do.)	0·001879	Antimony (cast)	0·000985
Brass (hammered)	0·001828	Platinum (forged)	0·000881

Note on Nitro-glycerine and other Xyloids. By J. Baker Edwards, *Ph.D., Lecturer on Chemistry and Toxicology, Royal Infirmary School of Medicine, Liverpool.*

The author stated that he had made a considerable number of experiments upon various animals to ascertain the physiological effects of these substances, some of which he found possessed poisonous properties.

Dr. De Vry introduced the substance known as nitro-glycerine or glonoïne, to the notice of the British Association at Ipswich, and observed that from some experiments made upon rabbits, he concluded that it was not a poison. The experiments of Mr. Field, however, showed that it possesses a powerful physiological action upon man; and the author had in a great number of instances observed and experienced violent and protracted headache and irregularity of the heart's action follow the administration of a single drop; upon animals, viz. frogs, birds, rabbits, and cats, doses of from four to ten drops produce at first similar symptoms and dilation of the pupil of the eye. After apparent recovery from these first effects, a secondary chain of symptoms set in, viz. vertigo, trismus, violent tetanic convulsions, lasting in some cases for three or four hours, and then terminating in death by exhaustion. Shortly before death, extreme contraction of the pupil of the eye is observed, and the animal becomes stupefied and nearly unconscious; when the animal is disturbed, however, a convulsive paroxysm takes place, resembling that produced by strychnine.

Similar experiments were made upon xyloidine from sugar, washed until all bitterness was removed. No effects were produced.

Upon xyloidine from starch, which produced convulsions in the rabbits; but no fatal effects were produced in a quantity of ten grains.

Upon pyroxyline collodion, which produced no marked effect.

It is possible in the latter case the ether is antidotal to the peculiar action of xyloidine, for when administered to persons suffering from the effects of glonoïne it affords prompt relief. The author had not concluded his experiments upon this subject.

A Process for the Estimation of Actinism. By R. J. Fowler.

In the ninth volume of Gmelin's 'Handbook of Chemistry,' we find it stated that "oxalate of ammonia mixed with aqueous protochloride of mercury is decomposed under the influence of light, yielding sal-ammoniac, calomel, and carbonic acid;" it is also stated that "the mixture of the two solutions remains clear in the dark, in daylight it becomes turbid in six minutes, and in the course of an hour deposits calomel, which in sunshine quickly falls down in soft flakes surrounded with bubbles of carbonic acid. The filtrate no longer contains mercury, but chloride of ammonium and undecomposed oxalate of ammonia."

On seeing this, the author conceived that here *might* be the elements of a process for actinometry; the following are the results of experiments which he has tried on the subject.

It is perfectly correct that the two solutions named may be kept mixed unchanged for an indefinite period in the dark, that the precipitation of calomel begins in about fifteen or twenty seconds in full sunshine, and that this precipitate ceases immediately the vessel containing the solutions is removed from solar influence, showing that the action is not *continued* in darkness after the chemical change has been partially effected; that the action of the actinism is not in this case calalytic. When three tubes of the mixed solutions are exposed to pretty uniform light, No. 1 for ten minutes, No. 2 for twenty minntes, and No. 3 for forty minutes, the results are that the tube that had been exposed twenty minutes contained twice the bulk of precipitate of that which had been exposed but ten minutes, and the tube with forty minutes' exposure contained twice the bulk of the twenty minutes. If the exposure of the solutions be continued several hours, the vessel containing them will be completely filled with a magma of the precipitated calomel*.

From these experiments it is concluded that the mixture of solutions of oxalate of ammonia and protochloride of mercury is very sensitive to light; that as this action of light is not catalytic, all the precipitate obtained from the solutions may be considered as being produced by solar influence alone; and lastly, that a definite amount of precipitate is produced by a definite amount of actinic force; thus proving that there are elements of uniformity and certainty in the behaviour of the mixed solutions under the influence of light, from which a certain method for estimating the actinic force may be formed.

If extreme delicacy be required in the estimations, the precipitated calomel might be collected, washed, and dried; but if this is not desired, narrow graduated tubes might be used for exposing the mixed solutions, and the amount of precipitate read off after standing a certain time in the dark.

The author used in these experiments nearly saturated solutions of the two salts, but the formation of calomel takes place in solutions far removed from the point of saturation; for if a drop of solution of the protochloride of mercury containing only $\frac{1}{1300}$ of a grain of that salt be added to 300 grains of a solution of oxalate of ammonia and exposed to the light, the calomel is precipitated in a light powder; and this delicate reaction may therefore be used as a confirmatory test for the presence of the protochloride of mercury.

It would be interesting to know whether the absorbed actinism of M. Niépce de St. Victor would affect the mixed solutions. The author has tried several experiments in this direction, but not with sufficient success to warrant any positive assertions.

On a Method of Observation applied to the study of some Metamorphic Rocks; and on some Molecular Changes exhibited by the action of Acids upon them. By ALPHONSE GAGES, *Curator of the Museum of Irish Industry, M.R.I.A.*

The author, while admitting that the ordinary method of analysing rocks gives their absolute composition, is of opinion that it does not give any information as to their genesis or decomposition. The preliminary mechanical operations to which the specimens to be analysed are submitted wholly destroy their peculiar state of aggregation, and mix up substances that may not have been in combination. He accordingly proposes a new method of examination, which is applicable in a great many cases, and which is capable of leading to extremely important results in connexion especially with metamorphic rocks. His method is to expose fragments or thin laminæ cut in certain directions, or whole crystals to the action of acids, alkalies, or other solvents for a certain time.

The author gave several examples illustrative of his method, of which the following are the most interesting.

A fibrous dolomite of Miask in the Ural Mountains, analysed by the ordinary method, yielded—

Carbonate of lime	57·483
,, magnesia	40·974
Sesquioxide of iron and alumina	0·411
Water and organic matter	0·239
Silica	1·095
	100·202

* The mixed solutions may be boiled in darkness without any precipitation of calomel.

Considered alone, these numbers would lead to the mere conclusion that the rock was a dolomite; but by operating on a moderately sized fragment cut in the direction of the fibres, with dilute hydrochloric acid, for some days, a skeleton remains of asbestiform tremolite having the following composition:—

Silica	68
Magnesia	29

—a result which shows that the dolomitic rock is a subsequent formation to the tremolite.

The new mode of conducting the examination of rocks, depending upon the mechanical difference of their preparation, was further advantageously contrasted by the author. Some varieties of magnesite leave silico-gelatinous residues, by which the transition from meerschaum to a replacing pseudomorphite of carbonate of magnesia may be followed. Again, crystal of Thomsonite boiled in hydrochloric acid, deposits, after removal of the alkali, a gelatinous transparent precipitate, and an opaline skeleton remains, presenting the outlines of the primitive crystal, thus exhibiting the stages of alteration through which these crystals pass. The opals found in the basaltic districts of the North of Ireland have most probably been derived from the gelatinous silica of the decomposed zeolites, while the hydrophane of the same locality resembles in a remarkable manner some skeletons artificially obtained from a laminated magnesite derived from the decomposition of basalt, and described by General Portlock in his 'Geological Report.' This mineral, treated by acids, leaves a skeleton of pure amorphous silica lighter than water, and having the perfect form of the primitive substance, consisting of thin laminæ superimposed like the leaves of a book. After immersion in water for a sufficient length of time, it becomes translucent, and acquires all the characters of certain varieties of hydrophane. If left exposed to the air for some time, it loses the greater part of its water, but retains a mean quantity of about 6·40 per cent., which corresponds with the formula $3SiO^3, HO$ given by Beudant for an opake white opal from Castellamonte.

As an illustration of the decomposition and subsequent reconstruction of rocks, the author referred to a pseudomorphite of laminated quartz-rock, derived from magnesite, which, though partially crystalline, retained traces of amorphous silica. It would appear that the original rock, after the disappearance of some of its constituents, had been infiltrated by the silica of alkaline silicates derived from the decomposition of trappean rocks. The petrifaction of fossil wood from the vicinity of Lough Neagh may be referred to the same class of phenomena.

Mountain leather and cork from Londonderry, leave, when treated by acid, a light spongy skeleton analogous to varieties of *nectique* quartz. All these substances are evidently the result of a more or less advanced state of alteration of hornblendic and augitic rocks; sometimes the decomposing silicates are entirely replaced by carbonates of lime and magnesia, or with carbonate of lime alone, and the original mineral is traceable only in the form of a thin superficial film on both sides of the newly-formed carbonates. Serpentine, cut into thin laminæ and treated by acids, exhibits in a great number of instances the original mineral substance from which it has been derived. The author concluded by stating that the simple treatment of acids acting upon thin laminæ was an efficient means of distinguishing true serpentine, which leave a skeleton of amorphous silica, from many rocks resembling the former lithologically.

On a new variety of Pyro-electric Wavellite. By ALPHONSE GAGES, *M.R.I.A., Curator of the Museum of Irish Industry, Dublin.*

The first specimen with which the author became acquainted, was presented to him by Mr. G. H. Kinahan of the Geological Survey, and was part of a block found in the drift on the banks of White River, four miles south of Loughhill, resting on coal-measures. It was accompanied by blocks of limestone, trappean breccia, syenite and granite. Wavellite has also been found by Messrs. Jukes and Kinahan in the lower bed of the coal-measures, just above the limestone, about three miles north-west of Cahirmoyle.

The present specimen answers in some respects to the description of Fischerite or Peganite, as given by Dufrenoy and Dana.

It is composed of small crystals of an emerald-green colour, mingled with white crystals forming mammillated concretions, cementing fragments of a quartzose grit.

In other instances, the mineral forms the cement of a conglomerate of a black chert-like variety of jasper.

It exhibits slight pyro-electric properties. At 100° C. it loses a part of its water. Its analysis gave—

Water	23·565
Alumina	36·160
Peroxide of iron	1·812
Phosphoric acid	30·881
Silica	3·615
Oxide of nickel	·325
Phosphate of lime (apatite)	1·578
Fluorine	trace
Quartz	1·003
	98·939

Hence the formula $5\left\{\begin{matrix}Al^2O^3\\Fe^2O^3\end{matrix}\right\}3PO^5+18HO$ may be deduced.

Hermann considers Fischerite to be $2Al^2O^3, PO^5+8HO$, and the Peganite of Breithaupt as only differing from it in containing six equivalents of water. The colour of this last is due to oxide of copper, but in the present case oxide of nickel is the source. Five equivalents of the Irish mineral, plus one equivalent of Al^2O^3, will be equal to three equivalents of Peganite.

The author only proposes this formula as an expression of a single analysis; but as a great many phosphates of alumina have hitherto been confounded with Wavellite, he is of opinion that a complete examination of the whole series would be a desideratum.

A conglomerate of quartz cemented by white Wavellite was also found at some distance from the first specimen.

It is worthy of observation, that nearly all the varieties of the mineral are to be found in this carboniferous locality; and as many of these appear to be of very recent origin, it is possible that some phosphatic deposits may exist in the locality.

On Electrical Discharges as observed in highly rarefied Carbonic Acid in contact with Potash. By J. P. GASSIOT, *V.P.R.S.*

The author exhibited a tube in which was placed a piece of caustic potash, and explained that the tube had been previously charged with carbonic acid, and after being exhausted, had been hermetically sealed. The small residuum of carbonic acid was therefore in contact with potash. This tube, when cold, showed the stratified discharge; but on melting the potash, the discharge merely passed in the form of a wave without stratifications from one terminal to the potash, and from the potash to the other terminal. As the potash cooled, the discharge reassumed its original appearance.

On reciprocal Decomposition between Salts and their Acid Solvents. By J. H. GLADSTONE, *Ph.D., F.R.S.*

It has been recently shown, that when two salts MR and M′R′ are mixed in solution, a partial interchange of their component parts ensues, with the production of amounts of MR′ and M′R, depending among other circumstances on the relative quantities of the original salts. If to such a mixture in solution, an additional amount of either MR′ or M′R be added, it will alter the state of equilibrium, and itself suffer reciprocal decomposition, producing an additional amount of both MR and M′R′ in equivalent proportions. An acid, that is a hydrogen compound, HR, comports itself in such circumstances in the same way as a metallic salt. Hence it may be anticipated that when a salt MR′ which is insoluble in water is dissolved in some aqueous acid, reciprocal decomposition will also ensue, and the addition of either MR or HR′ to the solution will cause a precipitate of the original insoluble salt MR′. The author had already adduced instances, in the Quarterly Journal of the Chemical Society, in-which this extraordinary result does actually ensue; he now drew attention to the fact that it invariably occurs, and showed that the reasoning applied equally to cases in which the salt MR′ is not insoluble in water, but only less soluble than MR or HR′.

Experiment confirmed this view; thus, among other instances, a saturated solution of sulphate of silver in aqueous nitric acid gives a crystalline deposit of the sparingly soluble sulphate, if it be treated with a strong solution of either nitrate of silver or sulphuric acid. Observations on the crystals that separate from solutions of sulphate of soda, or of nitrate of potash, in hydrochloric acid, when similarly treated, showed at once the influence of mass, and confirmed the conclusion that at all times four compounds coexist in the solution. The author's experiments on sparingly soluble salts dissolved in acids had all indicated that the law of reciprocal decomposition holds good in such cases also, and had afforded additional support to the inference, that *if an acid* HR *dissolve a salt* MR′ *to saturation, the addition of either* MR *or* HR′ *will cause the production of more* MR′ *than the acid can keep in solution,* and which must accordingly precipitate or crystallize out.

The former experiment of dissolving ferric phosphate in hydrochloric acid had been tried in absolute alcohol instead of water, with a still greater indication of the non-conversion of the whole of the iron into the state of chloride, and an equally clear optical demonstration that the addition of more hydrochloric acid increased the amount of ferric chloride present.

On a remarkable Deposit of Carbonate of Lime about Fossils in the Lower Lias of Dorsetshire. By George Gladstone, *F.C.S.*

The object of this paper was to bring before the Section some very curious specimens of fibrous carbonate of lime, which the author found during a recent visit to Lyme Regis.

The lower lias shales, which are there very fully developed, are in many instances parted by bands of fibrous carbonate of lime, some of which are less than a quarter of an inch thick, while others are several inches in thickness: the fibre runs exactly at right angles to the surface of the bands, through the middle of which a dividing line generally runs, as if the deposit has originated on both the upper and under sides simultaneously and met in the centre.

In some places these bands are full of what appear like ammonites, having the markings perfect on both sides, and standing in high relief, as if they were the actual shells. On examining them minutely, however, it is found that they are composed merely of two layers of this fibrous carbonate of lime with the shell of the ammonite in a crushed and flattened state in the centre, the fibre of the lime still maintaining the same direction as in the rest of the band, viz. perpendicular to the flattened shell, and varying in length so as to preserve all the curves and ridges which the shell had when perfect. In one specimen, where the outer whorl of the ammonite being of stronger texture and filled with sediment, had not been crushed, the same deposit appears, forming a complete fringe of even thickness, and thus preserving all the form of the shell beneath.

Some other shells exhibited the same curious appearance, but they are much less numerous than the ammonites, which must have swarmed at the time these beds were deposited.

On the Alkaline Waters of Leeds. By W. Huggon.

The author gave the results of an analysis of a gallon of water from Ripley's Well, Holbeck. This alkaline water appears to contain a larger amount of alkaline matter than any in England. The nearest approach to it is the water of the artesian well in Trafalgar Square, which, according to the analysis of Abel and Rowney, contains 18 grains of carbonate of soda in the gallon, and 20 grains of the whole solid matter is chloride of sodium.

I have examined ten of the alkaline waters of Leeds, and found them to vary in the quantity of carbonate of soda, "which is the alkaline substance they contain," from 24 grains to 45 grains per gallon of water.

The water from Mr. Ripley's artesian well, Holbeck, contains the largest amount of carbonate of soda, viz. 45 grains per gallon. It also contains ammonia, sulphide, iodide, and bromide of sodium.

This water I selected for a complete analysis, which shows one gallon to be of the following composition:—

Saline constituents—	Carbonate of lime	2·151
	" magnesia..	1·023
	" iron......	0·045
	" soda	45·620
	" ammonia..	0·045
	Sulphate of potash ..	1·303
	Chloride of sodium ..	52·123
	Sulphide of sodium ..	0·740
	Iodide of sodium	0·022
	Bromide of sodium ..	trace
	Silicate of soda......	1·312
	Silica..............	0·531
	Alumina	0·150
	Organic matter......	0·227
Total in 70,000 grains............		105·292 grains.

This water also contains carbonic acid gas, nitrogen, and sulphuretted hydrogen: a large amount of carburetted hydrogen is evolved at its source.

Some Account of Professor Schönbein's *latest experiments on the Allotropic Conditions of Oxygen. By* H. Bence Jones, *M.D., F.R.S.*

On an Instrument for Measuring the Constant Intensity of Ozone. By Edwin Lankester, *M.D., F.R.S.*

This instrument consisted of two small rollers included in a box, which were moved by means of ordinary clock-work. Over the roller, a strip of paper, prepared with iodide of potassium and starch, is allowed to revolve, the paper becoming exposed to the air for an inch of its surface, in the lid of the box. Twenty-four inches of paper pass over the rollers in the course of the twenty-four hours, which thus registers by its colour the intensity of the action of ozone in the atmosphere. By this instrument the intensity of the ozone for every hour in the twenty-four could be registered, and *minima* and *maxima* with an average be ascertained. The register of ozone could also be compared with those of the anemometer, and the relation of ozone to the direction and force of the wind ascertained. Dr. Lankester pointed out the importance of ascertaining the presence of ozone, on account of its undoubted relation to health. He drew attention to a series of tables which had been drawn up from the registrations of the anemometer made at London, Blackheath, and Felixstow, on the coast of Suffolk. From these it was seen that the relation of these three places were as 0·22 and 55. The instrument acted also as a clock, and the time could be accurately marked upon the ozonized paper.

On the Annual Yield of Nitrogen per Acre in different Crops. By J. B. Lawes, *F.R.S., F.G.S., and* J. H. Gilbert, *Ph.D., F.C.S.*

In a paper given last year at the Dublin Meeting, on the question of the assimilation of free nitrogen by plants, and some allied points*, the authors had stated in general terms, that the amount of nitrogen yielded per acre, per annum, in different crops, even when unmanured, was considerably beyond that annually coming down, in the forms of ammonia and nitric acid, in the yet measured and analysed aqueous deposits from the atmosphere. The investigations then referred to were still in progress; and a desirable introduction to the record of the results would obviously be, to

* Preliminary Notice of Researches on the Assimilation of Nitrogen by Plants. By Messrs. Lawes, Gilbert, and Pugh.

illustrate, by reference to direct experiment, that which had been before only assumed, regarding the yield of nitrogen in our different crops. To this end the annual produce of nitrogen per acre had been determined, in the case of various crops, which were respectively grown for many years consecutively on the same land; namely, wheat, fourteen years; barley, six years; meadow hay, three years; clover, three years out of four; beans, eleven years; and turnips, eight years. In the majority of the instances referred to, the yield of nitrogen had been estimated, both for the crop grown without manure of any kind, and for that with purely mineral manure, that is, excluding any artificial supply of nitrogen. It was the object of the present communication to give a summary view of some of the facts thus brought to light.

Beans and clover were shown to yield several times as much nitrogen per acre as wheat or barley. Yet the growth of the leguminous crops, *carrying off* so much nitrogen as they did, was still one of the best preparations for the growth of wheat; whilst *fallow* (an important effect of which was the accumulation within the soil of the available nitrogen of two years into one), and *adding nitrogenous manures*, had *each* much the same effect in increasing the produce of the cereal crops.

Other experimental results were adduced, which illustrated the fact, that four years of wheat, *alternated with fallow*, had given as much nitrogen in the eight years as eight crops of wheat *grown consecutively*. Again, four crops of wheat, grown in alternation with *beans*, had given nearly the same amount of nitrogen per acre as the four crops grown in alternation with *fallow*; consequently, also much about the same as the eight crops of wheat grown consecutively. In the case of the alternation with *beans*, therefore, the whole of the nitrogen obtained in the beans themselves, was over and above that which was obtained, during the same series of years, in wheat alone, —whether the latter was grown consecutively, or in alternation with fallow.

Interesting questions arose, therefore, as to the varying sources, or powers of accumulation, of nitrogen, in the case of crops so characteristically differing from one another as those above referred to.

It had been found that the leguminous crops, which yielded in their produce such a comparatively large amount of nitrogen over a given area of land, were not specially benefited by the direct application of the more purely nitrogenous manures. The cereal crops, on the other hand, whose acreage yield of nitrogen under equal circumstances was comparatively so small, were very much increased by the use of direct nitrogenous manures. But it was found that, over a series of years, only about four-tenths of the nitrogen annually supplied in manure for wheat or barley (in the form of ammonia salts or nitrates), were recovered in the immediate increase of crop. Was any considerable proportion of the unrecovered amount drained away and lost? Was the supplied nitrogenous compound transformed in the soil, and nitrogen in some form evaporated? Did a portion remain in some fixed and unavailable state of combination in the soil? Was ammonia, or free nitrogen, given off during the growth of the plant? Or, how far was there an unfavourable distribution, and state of combination, within the soil, of the nitrogenous matters applied directly for the cereal crops,—those, such as the leguminous crops, which assimilated so much more, gathering with greater facility, and from different ranges of soil, and leaving a sufficient available nitrogenous residue within the range of collection of a succeeding cereal crop? These questions, among others, which their solution more or less involved, required further elucidation before some of the most prominent of agricultural facts could be satisfactorily explained.

Comparing the amount of nitrogen yielded in the different crops, when grown without nitrogenous manure as above referred to, with the amount falling in the measured aqueous deposits, as ammonia and nitric acid, it appeared, taking the average result of the analyses of three years' rain, that all the crops yielded considerably more, and some very much more, than so came down to the soil. The same was the case when several of the crops had been grown in an ordinary rotation with one another, but without manure, through two or three successive courses. Was this observed excess of amount in the yield over that in the yet measured sources, at all materially due merely to the extraction by the crops, of nitrogenous compounds previously accumulated within the soil? Was it probably attributable chiefly to the absorption of ammonia or nitric acid, from the air, by the plant itself, or by the soil? Was there any notable *formation* of ammonia or nitric acid, from the *free nitrogen* of the atmosphere? Or, did plants generally, or some in particular, assimilate this *free nitrogen*?

As already intimated, some of the points which had been alluded to were at the present time under investigation; the authors having in this the able cooperation of Dr. Pugh. Others, it might be hoped, would receive elucidation in the course of time. There of course still remained the wider questions—of the original source, and of the distribution and circulation, of *combined nitrogen*, in the soil, in animal and vegetable life on the earth's surface, and in the atmosphere above it.

On the Action of Hard Waters upon Lead. *By* W. Lauder Lindsay, *M.D.*, *F.L.S.*

It is, and has long been currently believed,—1. That where there is free access of atmospheric air, *pure* or *soft* waters, that is waters absolutely or comparatively free from saline ingredients, readily corrode or erode lead, and become impregnated, sometimes to a poisonous degree, with some of the salts thereof. 2. That the rapidity and extent of this solvent or corrosive action are proportionate to the purity of the water, that is, its freedom from neutral salts. 3. That *impure* or *hard* waters, that is waters containing a considerable amount of neutral salts, do not so affect or become impregnated with lead. 4. That such waters are prevented from acting on lead by, or in virtue of, their saline constituents, which exert a sort of protective or preservative power in regard to the lead. 5. That if a given water does not within a short period cause a white coating on freshly-burnished lead plates or rods, it may be regarded as destitute of any corrosive action, and may therefore be safely allowed to be kept in leaden cisterns and transmitted through leaden pipes.

The author's experiments and inquiries have led him to the following somewhat opposite conclusions:—1. That certain *pure* or *soft* waters *do not* act upon lead. 2. That certain *impure* or *hard* waters, in some cases containing abundance of the very salts which are generally regarded as most protective or preservative, *do act* upon lead. 3. That the rationale of the action in these anomalous or exceptional cases is very imperfectly understood. 4. That experimentation on the small scale and for short periods is most fallacious, and frequently dangerous, in regard to the conclusions thence to be drawn. 5. That water may, under certain circumstances, and to certain extents, contain lead without necessarily being possessed of poisonous action on the human system. 6. That water contaminated with lead may deleteriously affect certain members or individuals only of a community, family, or household. 7. That the use of water so contaminated is the obscure cause of many anomalous colic and paralytic affections.

One chief object of the paper is to illustrate the second of the latter propositions, viz. that *hard* waters frequently *do act* upon lead. The author tabulates the various theories or explanations that have been or that may be advanced to account for the action of such waters upon lead, as follows:—

1. Galvanic action from the contact of different metals, or of different qualities of the same metal, under water.
2. Unusually small quantity of,—
   a. The neutral salts generally, or in the aggregate.
   b. Particular neutral salts, such as the carbonates and sulphates.
3. Use of leaden covers to cisterns.
4. Long exposure of still water to the same surface of metal, as in the storing up of water in lead cisterns.
5. Great extent of surface of metal exposed to the action of water.
6. Unusually large proportion of carbonic acid in the water.
7. Unusually large proportion of atmospheric air in the water.
8. Presence of nitrite of ammonia in the water.
9. Presence of acids, derivable from decaying or dead animal or vegetable matter.
10. Presence of foreign bodies or accidental impurities.
11. Chemical or electro-chemical causes, with which we are at present unacquainted.

The author refers to the first of these theories or explanations—galvanic agency

—as one of great importance, and he strongly commends it to the notice of chemists and electricians as a subject still requiring to be worked out. It would appear that the necessary use of solder,—the presence of portions of other metals than lead in any form in contact with lead,—inequalities in the surface of the lead sheeting,—the use of lead from different factories and of different composition (as lead made with old solder, or containing silver unextracted),—may each and all determine galvanic action, which facilitates, to a dangerous degree, the corrosive action of hard water on lead. What renders galvanic action the more dangerous and the more important is, that it is strongest in hard waters, that is, in those containing more or less neutral salts, which, under other circumstances, would exert their usual protective influence on the lead.

The paper contains several illustrations of,—1. corrosion or erosion, to such an extent as to cause repeated leakage, of leaden cisterns, by waters of various degrees and kinds of hardness, or containing various kinds and amounts of neutral salts; and 2. the poisonous action of such water, when impregnated with lead, on the human body. It also contains a series of comparative chemical analyses, made with a view to ascertain the condition as to hardness, or the nature and amount of the saline constituents, as well as the action upon lead, of various waters used for culinary and drinking purposes in and around Perth.

The author refers to the *mechanical* and *chemical* means of protecting the lead of cisterns and pipes against the corrosive action of water. Of *mechanical* means, he gives as illustrations the coating of the lead with compositions of rosin and tallow, or similar substances; and the patent processes of Mr. Davis of Lambeth, London, for lining the interior of leaden pipes with tin, or with gutta percha, caoutchouc, gum-lacs or bitumen. The substitution of other metals—of wood, glass, earthenware, or gutta percha for lead—in the construction of cisterns and pipes, is also referred to. Of *chemical* means, he instances the addition to the water of powerfully protective salts, such as the phosphate of soda, or the iodide of potassium in minute proportion.

The author believes that cases of lead poisoning, in a minor degree, are still constantly occurring in all our large towns from the plumbeous impregnation of our drinking waters; and he impresses the necessity of inquiring at once into the condition of the water supply whenever obscure colic or paralytic complaints exhibit themselves, otherwise inexplicable, especially if it be found that several persons are simultaneously affected*.

On an improved Electric Lamp invented and manufactured by Mr. William Hart, *Edinburgh.* (*Communicated by* Dr. Stevenson Macadam, *F.R.S.E.*)

The relation which the several parts of this lamp bear to each other, will be better understood by following the route which the electricity takes in its travels through the lamp. The wire attached to one of the extremities of the battery is brought to a binding-screw, which is in metallic connexion with the cylindrical base of the arrangement and the lower charcoal rod. The latter is immoveable, and constitutes one of the poles of the voltaic battery. The wire coming from the opposite end of the battery is placed in a connecting screw (which is insulated from the cylindrical base by the insertion of a ring of ivory), passes up the centre of a hollow stem (also insulated from the cylindrical base by ivory), is led through a canal in the centre of an arm placed at right angles to the stem, and is then wound round an electro-magnet suspended in a vertical position from the arm. Thus far the wire is covered with silk, and hence does not come into metallic connexion with the other parts of the lamp; but having completed its required course, it is soldered to the electro-magnet, and thus becomes metallically connected with the upright stem and all its appurtenances, including a file-like rod, grasping the upper charcoal rod, which is moveable and forms the second electrode.

When the battery is not in action, the roughened or file-like rod, with its attached upper carbon pole, is not upheld by any device, but simply reclines on the lower

* The paper will be found published at length in the "Edinburgh New Philosophical Journal" for April, 1859.

carbon rod; but whenever the voltaic current is allowed to circulate, the electro-magnet is formed and its armature is drawn up; a ring connected with the armature compresses the halves of a hollow wedge; the upper edges of the wedge fix into the grooves in the file-like rod with its attached carbon, and in the general movement upwards the latter is slightly raised from the lower carbon, and the light is instantly produced.

It will thus be observed, that the ring attached to the armature performs two offices when drawn up towards the electro-magnet:—in the first place, rising from a narrower part, where it loosely surrounds the hollow wedge, it tightly embraces, when half-mast high, the wider part of the wedge, and compels it to set in tightly to the file-like rod; and in the second place, having firm hold of the wedge, it drags up that part with the now adherent roughened rod and upper carbon, and holds these suspended at the proper distance. The light continues to burn steadily till the charcoal points by combustion and the transference of carbon have their proper distance from each other increased to that point when the electricity ceases to flow; then the electro-magnet loses its attracting power, the armature and the attached ring fall down; the halves of the wedge, separate from each other, loose their hold of the file-like rod, and allow the latter to descend by the force of gravitation, till the upper charcoal pencil touches the lower carbon rod, when instantly the electrical current is re-established, the magnet is reformed, and the upper carbon is again drawn up. So momentarily does this extinguishing and relighting of the lamp occur, that the interval of darkness is hardly observable to the naked eye. In duration of time, as also in the convulsive throb which the moveable parts of the apparatus then give, the phenomenon greatly resembles the beat of the heart of an animal. The lamp may be accommodated to any size of battery sufficient to show the light. By means of a series of screws in connexion with the armature, and the supporting arm, the moveable and adjusting part of the lamp may be lowered from the electro-magnet or raised towards it. If the battery be small, then the lifting arrangement is screwed up near the magnet; whilst if the battery be large, and a corresponding amount of electricity at command, the regulators are placed further from the lifting power, and when the voltaic current traverses the arrangement, the moveable carbon is drawn up a greater distance, more space is presented between the carbon poles, and necessarily a longer and more dazzling arc of flame is formed.

On M. de Luca's *Claim to be the Discoverer of the Non-Presence of Iodine in the Atmospheric Air, Rain-Water, and Snow. By* Dr. Stevenson Macadam.

Note on the Production of a Frosted Surface on Articles made of Aluminium. By Stevenson Macadam, *Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry, Surgeons' Hall, Edinburgh.*

The attention of the author was directed to this subject, on the occasion of preparing several class medals from the rare metal aluminium. The metal was obtained direct from Paris in small ingots. The die-stamper in this country fused the bars of aluminium and recast the metal in a form of ingot mould, more suitable for the after operations. The metal bars thus obtained were subjected to rolling, then annealed, and the medals struck. Every care was taken to have the die perfectly clean and highly polished, and yet the medals were always obtained with a tarnished appearance on the surface, which rendered still more unacceptable the blue *zinc* hue which the aluminium presents when most free from surface blemishes. An attempt was made to get rid of the tarnished surface by friction or polishing, but this did not sensibly remove the stains. It was then resolved to *frost* the medals in the same way as silver articles are frosted, viz. by the employment of hydrochloric acid into which the heated metal is dipped; but the action of acids on aluminium was so slow, that they failed to produce the requisite effect, and their employment was dispensed with.

The author then introduced the aluminium articles into a solution of caustic potash raised to a temperature above blood-heat, which immediately attacked the metal, hydrogen being disengaged, and very shortly the aluminium assumed a fine white frosted appearance. The solution of caustic potash, when concentrated, acts very violently upon the aluminium; and if the metal were not speedily rescued, it would soon entirely disappear. Even a dilute potash solution at a blood-heat will slowly produce the frosted appearance.

The author suggests that the process now indicated may be found of service in the arts. Aluminium has hitherto proved itself to be unacceptable on account of its similarity in appearance to zinc, but now a frosted surface may be communicated to articles made of aluminium, which rivals that of frosted silver, and which possesses this great advantage over silver, that it is not liable to be acted upon by sulphuretted hydrogen, such as silver is, but continues to retain its fine white frosted appearance.

On the Combustibility and other Properties of the Rarer Metals. *By* J. A. Matthiessen, *Ph.D., F.C.S.*

The author gave a description of the very beautiful metals obtained from the alkalies and alkaline earths, which was illustrated by the exhibition of a variety of these metals, as attractive as unusual. The specimens of sodium, lithium, potassium, calcium, strontium, &c., were regarded with great interest, and their combustion in an intensely brilliant white light elicited frequent expressions of admiration. Their extreme lightness was dwelt on, lithium being lighter than any liquid, and possessing little more than half the specific gravity of water. From magnesium the combustion resulted in an ash hollow throughout.

On Chromatic Photographs. *By* John Mercer, *F.R.S.*

The author exhibited a number of coloured photographs, some on paper and others on calico, which had been prepared by the following process:—34 ozs. of sulphate of iron are converted into peroxalate; this is diluted to two gallons, and will impregnate 200 square yards of paper, the paper being floated on the solution till fully wet in the usual way. It is then exposed, and afterwards steeped in some solution which only acts on that part where the iron has been reduced from the per- to the prot-oxide. Red prussiate of potash and sulphuric acid act well, making the image blue, and leaving the ground white. Sulphocyanide of potassium and a salt of copper form another bath; the protoxide of the picture deoxidizes the copper, and the sulphocyanide of the suboxide of copper is fixed in the paper or cambric. This may be converted into the red copper prussiate. A vast number of colours may be obtained by replacing the iron or copper by other metals, such as lead, zinc, tin, mercury, silver, gold, or manganese. With these bases may be used various dyes, as madder, cochineal, murexide, logwood, galls, or quercitron bark, besides the iodides, chromates, prussiates, or oxides of the metals themselves and mixtures of these.

The author showed how the peroxalate paper might be used as a fair actinometer, by placing a slip between the leaves of a book, and pulling it out by steps every stated number of seconds. It is then easily converted into a graduated scale.

On the Relation of the Atomic Weights of the Families of the Elements. *By* John Mercer, *F.R.S.*

It is well known that where three or more elements form a well-defined group or family (such as lithium, sodium, and potassium), their atomic weights are found to stand in some simple relation to one another. The present paper pointed out many of these numerical relations, and those which arise when the equivalents of one group are subtracted from the equivalents of another group. Thus, for example, the lithium group may be supposed to be constructed in a similar manner to the group of organic radicals, hydrogen, methyl, ethyl, &c., as shown in the subjoined Table, where $b=1$.

Lithium	=	L	at. wt.	7	corresponding to	H
Sodium..	=	$b_2\,L_3$	,,	23	,,	$C_2\,H_3$
Potassium	=	$b_4\,L_5$	,,	39	,,	$C_4\,H_5$

Thus also, for example, if the atomic weights of the nitrogen group be subtracted from those of the fluorine group, the residue is in each case 5.

Carbon...$=5+1=6=ab+b$	corresponding to	
Boron ...$=5_2+1=11=2ab+b$	"	Methyle.
Silicon...$=5_4+1=21=4ab+b$	"	Ethyle.
Zircon...$=5_4+1=31=4ab+b$	"	Propyle.

The following family was also included in Mr. Mercer's calculations:—

Fluorine $=5+N=19$
Chlorine $=5+P=36$
Bromine $=5+As=81$
Iodine $=5+Sb=126$

From the tables exhibiting the possible construction of elements, the following may be taken as an example, introducing as it does two other families:—

4_2 =	O.		
4_3 =	——	Mg.	
4_4 =	S.		
4_5 =	——	Ca.	
4_{10} =	Se.		
4_{11} =	——	Sr.	
4_{16} =	Te.		
4_{17} =		Ba.	
$4+3$=		——	L.
4_5+3=		——	Na.
4_9+3=		——	K.

It will be observed that each member of the magnesium group is 4 in advance of the corresponding member of the oxygen group.

On the Atom of Tin. By Dr. W. Odling, *F.C.S.*

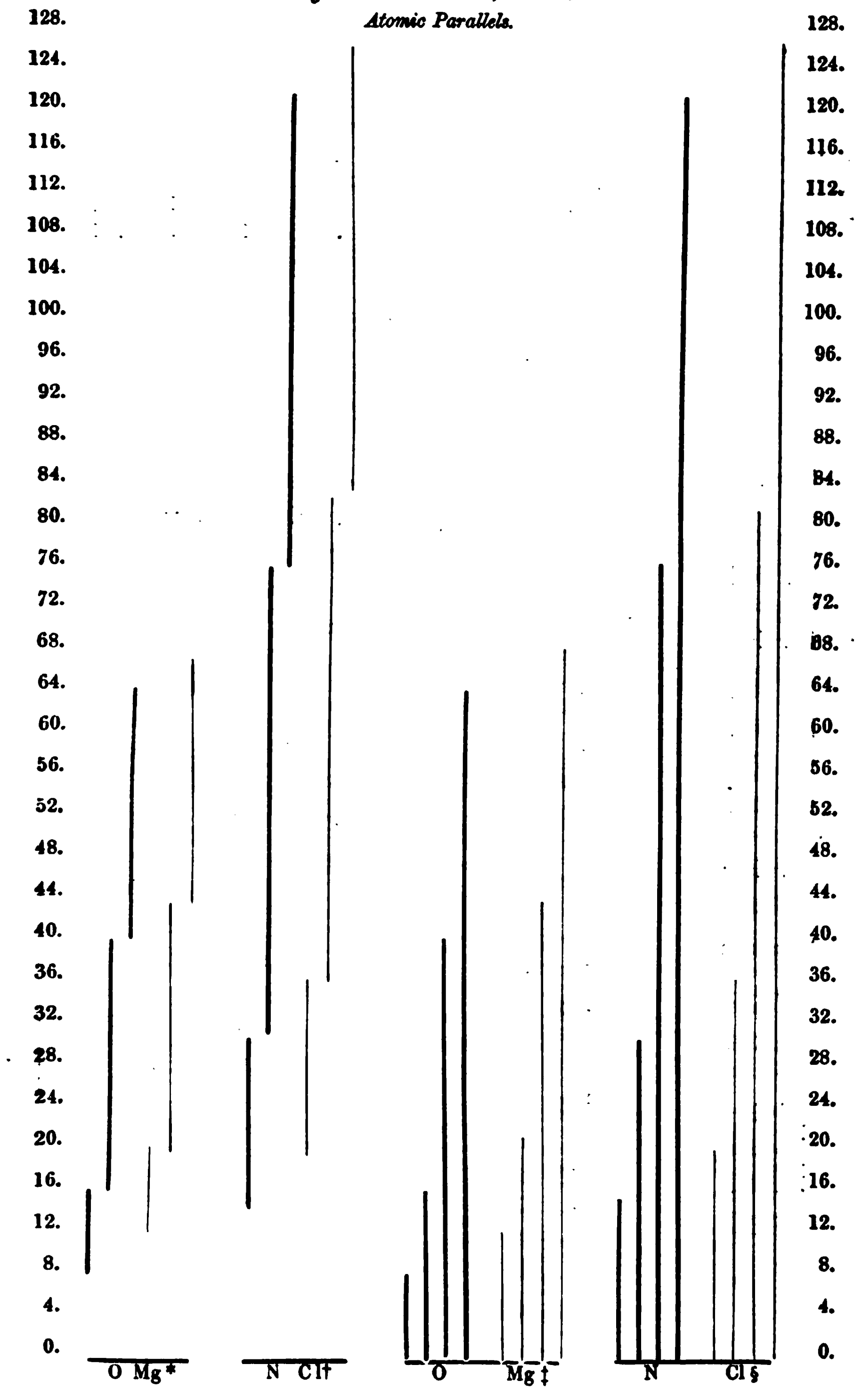
The author argued, from both original and recorded experiments, that the atomic weight of tin was not 59, as usually accepted, but the double thereof, or 118; and, consequently, that stannous salts were not protosalts, but bisalts; and stannic salts not bisalts, but quadrisalts. This view was supported by the following considerations; namely, that stannous oxide has the property of expelling carbonic acid from fused alkaline carbonates; that stannous oxide does not form any combination with carbonic acid; that stannous salts are completely decomposed by chalk and insoluble carbonates, even at ordinary temperatures; that stannous chloride is readily fusible and volatile, and is decomposed to a considerable extent by water; that stan-ethyl, or stannous ethyl, has not the properties of a prot-ethylide, but of a per-ethylide, as instanced by the facility with which it combines with oxygen and chlorine, and replaces the basic hydrogen of different acids; that the vapour-density of stannic chloride requires the existence of four atoms of chlorine in its molecule; and, lastly, that stannic fluoride corresponds closely to silicic fluoride, the molecule of which, as shown by its vapour-density, contains four atoms of fluorine.

On the Purple Dye obtained from Coal-Tar. By W. H. Perkin, *F.C.S.*

This dye, a specimen of which was exhibited, is a product of the oxidation of aniline by bichromate of potash. It is a bronze-coloured substance, dissolving in alcohol with a beautiful purple colour. It is difficultly soluble in water, but more soluble in acidulated water. Like indigo, it is perfectly decolorized by the hydrated protoxide of iron, the colour being restored again by exposure to the air. It dissolves in concentrated sulphuric acid, forming a green solution, which, upon the addition of water, precipitates the colour unchanged. It is not affected by digestion with an alcoholic solution of potash. It decomposes slowly at 250° C. It is applicable for dyeing and printing silk, cotton, or wool. Its colour is exceedingly intense, one pound of the solid substance dyeing no less than 200 lbs. of cotton a moderately dark lilac. The colours thus produced are very permanent, standing the action of light and heat, acids and alkalies. Samples of silk dyed with it were exhibited.

On the Atomic Weights of the Elements of Six Chemical Families.
By JOHN MERCER, *F.R.S.*

Atomic Parallels.



* Oxygen and Magnesian Groups, showing the steps or difference between each member; they are parallel, except that Mg is raised up 4°. † This pair, Nitrogen and Chlorine Groups, are the same, but Cl is raised up 5°. ‡ Oxygen and Magnesian, full lengths, Mg 4° longer. § Nitrogen and Chlorine Groups, full lengths, Chlorine 5° longer.

Carbon Group.

$C \ldots\ldots\ldots\ldots 6 = 6$	or	$5 + 1 = 6 = ab + b = CH + H$		$A = 4$
$Bo = 5 + 6 = 11$	„	$5_2 + 1 = 11 = 2ab + b = 2CH + H$	Meth.	$a = 4$
$Si = 5_3 + 6 = 21$	„	$5_4 + 1 = 21 = 4ab + b = 4CH + H$	Eth.	$b = 1$
$Zr = 5_5 + 6 = 31$	„	$5_6 + 1 = 31 = 6ab + b = 6CH + H$	Prop.	$ab = 5$

Lithium Group.

$L \ldots\ldots\ldots\ldots = 7$	$L + 1 = 8$	$L = 4 + 3 = 7$	
$Na = L + 16 = 23$	$Na + 1 = 8_2$	$Na = 4_5 + 3 = 23 = 8_2 + L = 2bL + L = 2CH + H$	Methyle.
$K = L + 16_2 = 39$	$K + 1 = 8_5$	$K = 4_9 + 3 = 39 = 8_4 + L = 4bL + L = 4CH + H$	Ethyle.

Oxygen and Magnesian Groups.

$O = 8$	$Mg = 12$	$O + 4 = Mg$	or	$8 + 4 = Mg$	$4_2 = O$
$S = 8_2^{-8}$	$Ca = 20^{-8}$	$S + 4 = Ca$	„	${}^{1-}8_2 + 4 = Ca$	$4_3 = \ldots Mg$
$Se = 8_5^{-8_3}$	$Sr = 44^{-8_3}$	$Se + 4 = Sr$	„	${}^{3-}8_5 + 4 = Sr$	$4_4 = S$
$Te = 8_8^{-8_3}$	$Ba = 68^{-8_3}$	$Te + 4 = Ba$	„	${}^{3-}8_8 + 4 = Ba$	$4_5 = \ldots\ldots Ca$

$$\left.\begin{array}{l} {}^{3-}8_{11} + 4 \\ 8 + 4 \end{array}\right\} = Pb$$

$4_{10} = Se$
$4_{11} = \ldots\ldots Sr$
$4_{16} = Te$
$4_{17} = \ldots\ldots Ba$
$4_{26} = \ldots\ldots\ldots\ldots Pb$

$2Mg = 24 = 8_3$
$Ba - Sr = 24 = 8_3$
$Sr - Ca = 24 = 8_3$
$\dfrac{Ba - Ca}{2} = 24 = 8_3$

Chlorine and Nitrogen Groups.

⎧ P − N = 17 = N + 3	N 14	X = presumed, or expected element
⎨ As − P = 45 = N_3 + 3	P = 2Y + 1 = 31	Y = N + 1 or 15
	3—	
⎩ Sb − As = 45 = N_3 + 3	As = 5Y + 1 = 76	Z = N + 3 = 17
	3—	
⎧ Cl − F = 17 = N + 3	Sb = 8Y + 1 = 121	
	3—	
⎨ Br − Cl = 45 = N_3 + 3	X = 11Y + 1 = 166	
	3—	
⎩ I − Br = 45 = N_3 + 3	Bi = 14Y + 1 = 211	

N = N + 0 = 14	or	N + 0 = 14	or	N = ... 14	or	N = ... 14
P = 2N + 3 = 31	„	2N + 3 = 31	„	P = Z + N = 31	„	P = N+3 + N = 31
As = 5N + 3_2 = 76	„	5N + 6 = 76	„	As = 2Z + N_3 = 76	„	As = 2P + N = 76
Sb = 8N + 3_3 = 121	„	8N + 9 = 121	„	Sb = 3Z + N_5 = 121	„	Sb = AsP + N = 121
X = 11N + 3_4 = 166	„	11N + 12 = 166	„	X = 4Z + N_7 = 166	„	X = 2As + N = 166
Bi = 14N + 3_5 = 211	„	14N + 15 = 211	„	Bi = 5Z + N_9 = 211	„	Bi = AsSb + N = 211

P = ... = 31	Bi − X = 45 or N_3 + 3	5 + 1 = C
As = NP + P = 76	X − Sb = 45 „ N_3 + 3	5_2 + 1 = Bo
Sb = 2NP + P = 121 Meth.	Sb − As = 45 „ N_3 + 3	5_6 + 1 = Si
X = 3NP + P = 166	As − P = 45 „ N_3 + 3	5_6 + 1 = Zr = P
Bi = 4NP + P = 211 Eth.	P − N = 17 „ N + 3	5_7 + 1 = ... Cl
		5_{15} + 1 = ... As

5_2 + 2_2 = N	.. 5_3 + 2_2 = F	F − N = 5	P − N = 17	5_{16} + 1 = ... Br
5_5 + 3_2 = P	.. 5_6 + 3_2 = Cl	Cl − P = 5	Cl − F = 17	5_{24} + 1 = ... Sb
5_{14} + 3_2 = As	.. 5_{15} + 3_2 = Br	Br − As = 5	Br − Te = 17	5_{25} + 1 = ... I
5_{23} + 3_2 = Sb	.. 5_{24} + 3_2 = I	I − Sb = 5	N + 3 = 17	5_{33} + 1 = ... X
5_{32} + 3_2 = X			HO + O = 17	5_{42} + 1 = ... Bi
5_{41} + 3_2 = Bi				

P + Np = As, + Np = Sb, + Np = X, + Np = Bi

P − 3 = N_2
As − 3 = N_3 P
Sb − 3 = N_4 P_2
X − 3 = N_5 P_3
Bi − 3 = N_6 P_4

Members of one of the five Chemical Families, taken from Members of another Chemical Family, showing the difference of the remainders.

	Remainders.	Difference.
O — L =	1	
S — L =	9	8
Se — Na =	17	8
Te — K =	25	8

	Remainders.	Difference.
Mg — L =	5	
Ca — L =	13	8
Sr — Na =	21	8
Ba — K =	29	8

	Remainders.	Difference.
N — L =	7	
P — Na =	8	1
As — K =	37	29

	Remainders.	Difference.
F — L =	12	
Cl — Na =	13	1
B — K =	42	29

	Remainders.	Difference.
Cl — L =	29	
Br — Na =	58	29
I — K =	87	29

	Remainders.	Difference.
N — O =	6	
P — S =	15	9
As — Sc =	36	21
Sb — Te =	57	21

	Remainders.	Difference.
N — Mg =	2	
P — Ca =	11	9
As — Sr =	32	21
Sb — Ba =	53	21

	Remainders.	Difference.
P — Mg =	19	
As — Ca =	56	37
Sb — Sr =	77	21
X — Ba =	98	21

	Remainders.	Difference.
As — Mg =	64	
Sb — Ca =	101	37
X — Sr =	122	21
Bi — Ba =	144	21

	Remainders.	Difference.
F — N =	5	
Cl — P =	5	0
Br — As =	5	0
I — Sb =	5	0

	Remainders.	Difference.
Mg — O =	4	
Ca — S =	4	0
Sr — Sc =	4	0
Ba — Te =	4	0

Ba — Sr =	24 =	8_3
Sr — Ca =	24 =	8_2
Ca — Mg =	8 =	8

P — L = 24		
	=	29
As — Na = 53		
	=	29
Sb — K = 82		

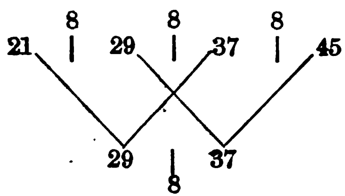
As — L = 69		
	=	29
Sb — Na = 98		
	=	29
X — K = 127		

Sb — L = 114		
	=	29
X — Na = 143		
	=	29
Bi — K = 172		

P — O = 23		
	=	37
As — S = 60		
	=	21
Sb — Sc = 81		
	=	21
X — Te = 102		

As — O = 68		
	=	37
Sb — S = 105		
	=	21
X — Se = 126		
	=	21
Bi — Te = 147		

F — O = 11		
	=	9
Cl — S = 20		
	=	21
Br — Sc = 41		
	=	21
I — Te = 62		



F — Mg = 7		
	=	9
Cl — Ca = 16		
	=	21
Br — Sr = 37		
	=	21
I — Ba = 58		

P — F = 12		
	=	28
As — Cl = 40		
	=	0
Sb — Br = 40		
	=	0
X — I = 40		

As — F = 57		
	=	28
Sb — Cl = 85		
	=	0
X — Br = 85		
	=	0
Bi — I = 85		

Te — Se = 24 =	8_3	
Se — S = 24 =	8_3	
S — O = 8 =	8	
K — Na = 16 =	8_2	
Na — L = 16 =	8_2	
Zr — Si = 10	5_2	
Si — Bo = 10	5_2	
Bo — C = 5	5	
Bi — X = 45 =	NP	$= N_3 + 3$
X — Sb = 45 =	NP	$= N_3 + 3$
Sb — As = 45 =	NP	$= N_3 + 3$
As — P = 45 =	NP	$= N_3 + 3$
P — N = 17 =	N+3	= N + 3
I — Br = 45 =	NP	$= N_3 + 3$
Br — Cl = 45 =	NP	$= N_3 + 3$
Cl — F = 17 =	N+3	= N + 3
N + 3 = 17		
2N + 3 = 31 =	P	
3N + 3 = 45 =	PN	

On a new Method for the Quantitative Estimation of Nitric Acid. *By* Dr. Pugh.

The author found that the action of nitric acid upon protochloride of tin, in a solution strongly acidified with chlorhydric acid, produced perchloride of tin and ammonia according to the formula ($NO_5+8SnCl+8HCl=NH_3+8SnCl+5HO$); but that the reaction was not completed, at the boiling-point, under ordinary pressure, even when maintained at this point for several hours. The results obtained at ordinary pressure with long-continued boiling, presented no constant value, and the maximum degree of oxidation afforded did not amount to quite three-fourths of the whole quantity required by the formula given above.

But on heating the mixture in an oil-bath, in glass-stoppered bottles, or in hermetically sealed tubes, to 160° Centigrade, the reaction was completed in 10 minutes. Upon this reaction he proposed to found two methods for the determination of nitric acid, either one or both of which could be used with the same quantity taken for analysis.

(a.) *First Method.*—This consists in ascertaining how much protochloride of tin is converted into perchloride during the reaction.

(b.) *Second Method.*—This takes advantage of the ammonia formed during the reaction. It is separated by distillation with an excess of fixed alkali and the distillate caught in a receiver, with a known quantity of acid, which is then treated according to Peligot's method for estimating nitrogen.

In the first method the amount of protochloride of tin converted into perchloride by the nitric acid is ascertained by triturating equal quantities of the tin solution before and after the reaction with the nitrate to be examined. This is done by ascertaining how much of a solution of known strength of bichromate of potash will be converted into the sesquioxide of chromium by a given quantity of the protochloride solution, according to the formula

$$2(CrO_3)+3HCl+3'SnCl=Cr_2O_3+3HO+3SnCl_2,$$

the point of complete chloridation being ascertained according to String's method by the intensely blue colour produced, on the liberation of free iodine, from iodide of potassium, in the presence of starch, by the first trace of chromic acid over that required to chloridate the tin.

From the reactions

$$NO_5+8(HCl+SnCl)=NH_3+8SnCl_2+5HO \text{ and}$$
$$KO.(CrO_3)_2+3(HCl+SnCl)=KO+Cr_2O_3+3(HO+SnCl_2),$$

we get

$$NO_5 \text{ corresponding to } \tfrac{8}{3}\left(KO.(CrO_3)_2\right);$$

and hence, without knowing the value of the strength of the protochloride solution, except in terms of the bichromate used, we get the amount of nitric acid present. Thus

Let A = weight of bichromate in a unit of volume of the solution used;

and N = the number of these units which corresponds to the whole tin solution used in a determination;

n = the number of the same units corresponding to the unoxidized portion of the tin, after the reaction with the nitric acid;

then $N-n$ = the number of units of volume of the bichromate solution which correspond to the nitric acid deoxidized;

$(N-n)a$ = weight of the bichromate corresponding to the nitric acid deoxidized;

$$\tfrac{3}{8}(N-n)a \times \frac{NO_5}{KO.(CrO_3)_2} = NO_5 \text{ present.}$$

The quantity (a) may be taken so small in relation to the unit of volume in which it is dissolved, that a quantity of that solution corresponding to ·00005 grm. nitric acid may be read off on the burette with ease. Such was the case with the five consecutive analyses below:—

Nitric acid taken	·00539 grm.
Nitric acid found............	·00541
" "	·00541
" "	·00541
" "	·00532
" "	·00546

For these experiments, sealed glass tubes, about ½ an inch in diameter and 5 to 7 inches long, were used.

When large quantities of nitric acid are supposed to be present, (a) must be larger, and consequently the extreme delicacy of the process is impaired; yet for ·078 grm. it gave accurate results to tenths of millegrams.

In the second process.

Let a = weight of normal acid (SO_3) used to absorb the ammonia given off in the distillate from the products of the action of the nitric and upon the protochloride of tin;

N = the number of volumes used in a single determination;

N′ = the number of volumes of an alkaline solution (of such strength as will allow accurate reading) which neutralize N volumes of the acid solution;

n = the number of volumes of the alkaline solution necessary to complete the neutralizing action after the absorption of the ammonia in question;

$$\text{then } (N'-n)\frac{N}{N'}\times a\times\frac{NO_5}{SO_3}=NO_5 \text{ present.}$$

This gave in four consecutive analyses,—

Nitric acid used	·00539
Nitric acid found	·0045
" "	·0049
" "	·0048
" "	·0047

The second process is not quite so exact as the first, because of the want of delicacy in the process for the determination of ammonia; yet it is true to two-tenths of a millegram of the nitrogen present.

In order to use the first process, no easily deoxidizable substance should be present. The author had not yet learned the full extent of the influence of such substances, but he hoped to be able to find means of eliminating all possible errors from this source.

On Animal Ammonia, its Formation, Evolution, and Office. *By the* Rev. J. B. Reade, *M.A., F.R.S.*

Alluding to the essay on 'The Cause of the Coagulation of the Blood,' by Dr. Richardson, to which the Astley Cooper Prize had been adjudged, the author pointed out how nearly Raspail had approached to the same conclusions as the essayist. In his treatise on Organic Chemistry, he says, "the constant alkalescence of the blood, newly drawn from the vessels, and the coagulation produced in it by a diluted acid, do not leave room for a doubt that the menstruum of the albumen is an alkali. This alkali is soda, but more especially ammonia, of which no notice has been taken by the various authors, but the presence of whose salts in the blood may be distinctly recognized by the microscope." "If this principle," he adds, "be admitted, the spontaneous coagulation of the blood presents no inexplicable difficulty." Raspail's additional remarks only led him further from the truth he so nearly approached, and inconsistently he attributed coagulation to the evaporation of watery vapour only.

Many years since the author demonstrated before the Microscopical Society of London, the presence of ammonia in the breath and tissues of animals, but his conclusions were received with much hesitation. Now that its office as a solvent of the fibrine of the blood is generally admitted, he would proceed to inquire into its source. An experiment, by which the presence of ammonia in the perspiration of man and animals is shown, may be readily performed, but is not included in those given by Dr. Richardson. A glass vessel is moistened upon its inner surface with hydrochloric acid, and its aperture held against the skin after exercise has been taken. The fluid will yield evidence of hydrochlorate of ammonia, when submitted to microscopic examination.

Dr. Richardson has shown that the transmission of the vapour of blood through another portion of that fluid arrests coagulation. The same effect occurs when the breath is passed into blood.

Repeated experiments have shown that the ammonia eliminated in the breath varies greatly in different individuals at the same time, and in the same person at different hours of the day, and under altered conditions of rest, exercise, or fatigue. The small amount contained in the atmosphere inspired is quite inadequate to account for that excreted, and we must consequently regard it as produced within the body. The albumen and fibrine of the blood suggest themselves as capable of supplying the nitrogen and hydrogen requisite. If we may assume the blood to be the source of animal ammonia, let us look at the exquisite balance of chemical forces in its connexion with that fluid. Blood is feebly alkaline from fixed alkali or alkaline salt; not sufficiently so to hold fibrine in solution by this agency, but to a degree which ensures the volatile alkali being left free for this purpose, when formed in the closed chambers of the circulation. This view harmonizes with the fact, that the formation of ammonia is a continuous process; the portion which maintains fluidity at a given moment does not remain to exercise this office for hours or days; but carrying the fibrine to every part of the body to supply its waste, it is itself eliminated by the excretory surfaces.

On the Practical Application of Aluminium. By R. REYNOLDS, *F.C.S.*

The author presented for examination by the Section, a spoon made of this metal by Messrs. Coulson and Co., Sheffield. In this form, its lightness, as compared with the metals ordinarily used for such purposes, was very striking. A perfect polish had been attained, but its zinc-like tinge of colour made it differ from silver in appearance. The handles of a knife and fork by the same manufacturers were also exhibited. They closely resembled gold in colour, and were composed of an alloy of copper with 5 per cent. of aluminium. By varying the per-centage of the last-named metal from 5 to 10, any shade of gold colour is attainable.

On the Choice of Subject in Photography, and the Adaptation of different Processes. By W. L. SMITH.

On a new Method of Determining the Quantity of Carbonic Acid contained in the Air. By DR. E. SMITH.

On some Double Salts formed with Bichromate of Potash. By W. K. SULLIVAN.

In the description given in Gmelin's 'Handbuch,' of Fritzsche's process of preparing chromic acid, it is recommended carefully to add a warm solution of bichromate of potash to an excess of oil of vitriol, as any excess of the salt would crystallize out without being decomposed, and thus contaminate the chromic acid. It appeared to me improbable that bichromate of potash would separate under such circumstances; and having had occasion recently to notice the salt which separates, I found that it did not present the characters of bichromate, and that it contained sulphuric acid.

If a nearly boiling concentrated solution of bichromate of potash be treated with sufficient oil of vitriol to convert the whole of the potash into bisulphate, but not to precipitate the chromic acid, and be then set aside, an abundant crystallization of anhydrous bisulphate of potash will be formed. The crystals thus formed are often of considerable size, and beautifully exhibit the peculiar reaction of the anhydrous bisulphate with water, namely, of swelling up and becoming opake. The crystals are always coloured yellow by the adhering solution, but sometimes they appear to contain some chromate in combination; for even after having been repeatedly dried between folds of filtering paper, they yielded a mixture of bisulphate of potash in acicular needles and orange-red rhombic needles, when dissolved in water and recrystallized.

When somewhat less oil of vitriol was employed than in the last case, a beautiful salt composed of orange-red rhombic plates separated, which were readily decomposed by water, exhibiting the same phenomenon as the anhydrous bisulphate. When a quantity of the transparent crystals were placed upon a filter and washed with water, they gradually became opake, swelled up and changed to a pale orange yellow mass. When the washing was not carried too far, and the filter was placed upon a plate of dry plaster of Paris, so as to absorb the moisture, the substance still exhibited the original form of the undecomposed salt, but the crystals were quite opake and friable. This pseudomorphic residue, when dissolved in water and the solution set aside to crystallize, yielded acicular crystals of bisulphate of potash and an orange-red salt in rhombic needles.

This remarkable mode of decomposition can only be accounted for by supposing the salt to contain bisulphate of potash. The determination of the sulphuric and chromic acids gave numbers, which upon this view lead to the very simple formula

$$KO, HO, 2SO_3+KO, 2CrO_3.$$

The strangeness of such a combination (for I am not aware that any similar one has been observed) makes me hesitate even to suggest it as an explanation of the phenomena observed, especially as I have only very partially examined the subject as yet.

There appears to be several other salts of the same class. I have obtained, for example, compounds which, upon the supposition of their being double salts of bisulphate of potash, contained an amount of sulphuric acid and chromic acid respectively, which would lead to the formulæ—

$$KO, HO, 2SO_3+2(KO, CrO_3)$$
$$KO, HO, 2SO_3+3(KO, CrO_3).$$

The formation of these salts, and indeed the action generally of oil of vitriol upon a solution of bichromate of potash, affords a beautiful example of the influence of mass upon chemical affinity.

When the first salt was dissolved in water and the solution evaporated and set aside, a salt crystallized out which did not become opake in water, and which could be recrystallized without change. Its analysis led to the formula

$$KO, SO_3+3(KO, CrO_3).$$

By using a slight excess of bichromate of potash in preparing chromic acid by Fritzsche's process, and dissolving the precipitated red acid in a small quantity of cold water, Reinsch obtained a yellow salt as a residue, which crystallized in broad rhombic needles united together in stellated masses. To this salt he assigned the formula $KO, SO_3+KO2CrO_3$. This salt appears to me to have been a product of the action of water upon one of the salts which are formed in concentrated solutions in which bisulphate of potash can be formed. I obtained this compound among the products of decomposition of one of the salts which I have suggested to contain bisulphate of potash.

I have obtained several other combinations which I have not yet examined, among which I may mention the following:—

1. I added a considerable quantity of oil of vitriol to the mother-liquor from which the salt $KO, HO, 2SO_3+KO, 2CrO_3$ had on one occasion separated, and then evaporated it briskly and set it aside. While hot it was of a deep brown colour, and crusts of chromic acid formed on the side of the vessel; as it cooled, it grew turbid, and the colour gradually became paler and of a purer yellowish red, as if the whole of the free chromic acid had again entered into combination*. After a short time, small crystalline scales made their appearance in the liquid, having the lustre and very much the appearance of spangles of metallic gold. They floated upon the surface of the liquid, and acting as nuclei, they shot out in fan-like masses, the borders of which got covered with a delicate fringe of needles of chromic acid. They arranged themselves on the bottom of the basin in warty masses about the size of a half-walnut. They were of extreme delicacy, so that the moment the vessel was disturbed they got detached and floated in the liquid like scales of iodide of lead. They were rapidly filtered through a funnel stopped with broken glass; and as they continued to dissolve during the filtration, they were put upon a plate of dry plaster of Paris. The dried residue looked very much like chromic acid, except that it had a distinct orange shade, and was foliated.

2. When the mother-liquor of one of the supposed bisulphate salts was mixed with another portion in which the chromic acid had been reduced to the state of Cr_2O_3 by alcohol, and set aside, small crystals of chrome-alum separated, but mixed with another

* This change may be observed in all cases where sulphuric acid is mixed with bichromate of potash.

salt in the form of brilliant bronze-coloured scales, strikingly resembling the bronze-coloured mica of some granites. This salt contains sulphuric acid; but whether all the chrome exists as chromic acid, I have not yet ascertained; I have failed in reproducing it.

3. I treated a boiling concentrated solution of bichromate of potash with glacial phosphoric acid and set it aside until the following day; a pale orange-red salt crystallized out in small nacreous scales. A portion of this salt, dissolved in water and set aside to crystallize, yielded a beautiful salt consisting of well-developed rectangular prisms of remarkable brilliancy. One feature of the action of phosphoric acid was, that the solution, no matter how much of the glacial acid was added, did not deepen in colour: it rather indeed became paler, and at no time did there appear to exist any uncombined chromic acid in solution.

On the Constitution of the Mineral Portion of Bones, and the Analysis of Common Bone-ash, Animal Charcoal, &c. By Professor VOELCKER, *Ph.D., F.C.S.*

Heintz of Berlin maintains the phosphate of lime to exist in a tribasic form, but found in human and other bones an excess of lime, combined neither with PO^5 nor CO^2. This he regards as fluoride of calcium, and consequently records as much as 3·85 per cent. of that substance as existing in bones. This, however, is simply the result of calculation from the excess of lime. The author had made many experiments to determine fluoride of calcium in bones, but without success; although when he added 1 per cent. of that substance to pure phosphate of lime, it could be readily determined.

When a dilute acid solution of bone-ash is precipitated by ammonia, the author has always found as much lime as is contained in the tribasic salt, and usually more, as carbonate of lime will be found to fall down with the precipitate in spite of all precaution; this is especially the case when the precipitation has been accompanied by heat. When conducted in the cold, and reprecipitated, the result agrees very closely with tribasic phosphate. In proof of the discrepancies of the process of precipitation, are the following experiments:—

	I.	II.
1. Bone-ash gave precipitated phosphates	75·84	73·29
2. Ditto	76·21	79·03

Animal charcoal gave—

First precipitation	77·46
Dissolved and reprecipitated	73·63
Re-dissolved " "	72·96

The direct determination of phosphoric acid gave 33·34=tribasic phosphate 72·23 per cent. The author much regretted the discredit brought upon chemistry by the great variations in commercial analyses of these substances, and alluded to a practice adopted by some chemists of regarding the precipitate as $8CaO+3PO^5$, and afterwards re-calculating the phosphoric acid into the tribasic salt, by which their results became much too high. He considered it imperative to discard the precipitation process altogether, and to state the amount of phosphoric acid actually found, giving the per-centage of tribasic salt equivalent to this.

The author recommends the following plan for the commercial analysis of bone-ash, animal charcoal, &c., and has employed it for some time in his own laboratory. Moisture and organic matter are determined as usual. About 20 grains are dissolved in nitric acid, and the solution evaporated on a water-bath to dryness, which effects the conversion of any pyrophosphate into ordinary phosphate. The residue is taken up by the smallest possible quantity of nitric acid, then diluted with water, the sand removed and the solution filtered. This is precipitated by excess of oxalate of potash, and before removing the resulting precipitate, the liberated oxalic acid is nearly neutralized by potash, acetate of potash is added, and the whole boiled. By this means the oxalate of lime held in solution by free acid is thrown down. Filter and wash the precipitate, and concentrate the filtrate to a small bulk. Add a little tartaric acid to keep in solution any iron or alumina, and precipitate the phosphoric acid by ammoniacal sulphate of magnesia: after standing for twelve hours, filter, partially wash the precipitate, redissolve and throw down a second time. This precaution is necessary, as the first product is contaminated with oxalate of magnesia. The lime precipitate contains generally a variable quantity of phosphates of iron and alumina. To estimate these, dissolve it in hydrochloric acid, add ammonia, wash precipitate, redissolve from the filter, and throw down a second time without heat. When washed and dried, as burned, the weight is deducted from the first amount of which it is a part, and the result is pure carbonate of lime. The phosphate of iron and alumina being dissolved in hydrochloric acid, a little tartaric acid is added, and the phosphoric acid finally determined as phosphate of magnesia.

On the Carbonates of Alumina, Chromic Oxide, and Ferric Oxide. *By* W. Wallace, *Ph.D., F.C.S.*

On Chloro-Arsenious Acid, and some of its Compounds. *By* William Wallace, *Ph.D., F.C.S.*

In the course of a former series of experiments on the chloride of arsenic*, I observed that arsenious acid dissolved freely in the anhydrous chloride. Believing that a definite combination was formed, I have recently investigated the subject more fully, and have succeeded in preparing a new and highly interesting compound, to which I have given the name of chloro-arsenious acid. My examination of the acid and its compounds is still far from complete; but I purpose in the mean time to submit a short abstract of my results to the members of the British Association.

1. *Solution of Arsenious Acid in Chloride of Arsenic.*—When chloride of arsenic is heated to gentle ebullition in a small tubulated retort, the beak of which is inclined upwards, and powdered arsenious acid is gradually introduced, the solution of the latter appears to cease when the liquid contains equal equivalents of the two compounds. The readiest method of preparing this solution in quantity is to introduce a few ounces of arsenious acid into a flask, and pass hydrochloric acid gas through it until all the arsenious acid disappears. The flask should be agitated occasionally. The action is very violent, and is attended by the elimination of much heat. If the passage of the hydrochloric acid gas is continued as long as absorption takes place, pure chloride of arsenic is obtained. The nature of the reaction has been fully explained in the paper already referred to.

2. *Chloro-arsenious Acid.*—When the solution of arsenious acid in chloride of arsenic is gradually distilled until it begins to froth up, there separates, on cooling, a pasty, viscid, semi-fluid mass, from which the more liquid portion may be poured off. Analysis gave as follows:—

Arsenic	..	1=75	59·29
Chlorine	28·11	1=35·5	28·06
Oxygen	..	2=16	12·65
		126·5	100·00

The formula of this compound, therefore, is $AsCl^3+2AsO^3$ or $AsClO^2$, that is, arsenious acid in which one equivalent of oxygen is replaced by chlorine.

Anhydrous chloro-arsenious acid is a viscid fluid or a very soft solid, according to the temperature to which it is exposed. It is transparent, but has a brown colour, which does not appear to be owing to the presence of any impurity. It fumes slightly in the air, parting with a small portion of its chlorine as hydrochloric acid, and absorbing oxygen. When strongly heated, it boils up with considerable frothing, and affords a distillate of pure chloride of arsenic. When brought up to about the temperature at which arsenious acid sublimes, it leaves a glassy, hard, transparent substance, which was found to contain 10·94 per cent. of chlorine, agreeing with the formula $2AsO^3$, $AsClO^2$.

The fluid poured off from the chloro-arsenious acid was found, on analysis, to contain an amount of chlorine which corresponds with the formula $AsCl^3$, AsO^3. It is therefore similar to the solution prepared by adding arsenious acid to heated chloride of arsenic. I do not believe, however, that this liquid is a compound of these two

* "On Chloride of Arsenic," by Penny and Wallace, Phil. Mag. vol. iv. p. 361.

substances; if a definite combination at all, its constitution is probably $3AsO^2Cl$ $AsCl^3$.

Chloro-arsenious acid is also formed when chloride of arsenic is treated with a quantity of water not quite sufficient to dissolve it. On adding small successive portions of water to the chloride, the proportion of chlorine in the undissolved quantity gradually diminishes, until the last globules consist chiefly of the compound acid.

3. *Hydrated Chloro-arsenious Acid.*—Chloride of arsenic is dissolved in the smallest possible quantity of water (about 16 equivalents), and the solution set aside in a closed flask. In two or three days minute nucleated crystals begin to form; and these gradually increase until about one half of the liquid is occupied by them. A second crop of crystals may be obtained by placing a fragment of rock-salt in the mother-liquor: these take a long time to form, and are much larger and better defined than those which result from the first operation. The crystals may be well pressed with a platinum spatula, and then dried by pressure between numerous folds of blotting-paper. A portion was analysed which had been completely dried by powerful pressure, and the following results were obtained:—

Arsenic	51·80	1=75	51·90
Chlorine	24·97	1=35·5	24·57
Oxygen	..	2=16	11·07
Water	12·35	2=18	12·46
		144·5	100·00

The crystallized acid contains, therefore, two equivalents of water, and is represented by the formula $2HO, AsClO^2$. It becomes anhydrous over oil of vitriol, but at the same time loses 2 or 3 per cent. of chlorine. The crystals are exceedingly minute, and form in mammillated masses resembling the mineral *Prehnite.* The slowly-formed crystals are acicular, and collect in stellate groups, presenting, while in the liquid, a very beautiful appearance. The smaller crystals have a dazzling white colour, and emit a little hydrochloric acid on exposure to the air.

Chloro-arsenious acid combines with chlorides, as arsenious acid does with oxides. It appears to be bibasic, the two equivalents of water being capable of being replaced by two equivalents of an alkaline chloride. The ammonia-salt is the only one which I have as yet succeeded in obtaining in a distinctly crystalline form, and of definite composition. Potash and lime compounds have been obtained as white powders which contain much less than two equivalents of alkaline chloride; so that these compounds have probably only one equivalent of alkaline chloride, and one equivalent of basic water.

Two interesting reactions of the solution of terchloride of arsenic in water may here be mentioned: oil of vitriol immediately throws down the anhydrous compound, while chloride of calcium causes the separation of the chloride mixed with a small proportion of chloro-arsenious acid. The same reactions occur with a saturated solution of arsenious acid in concentrated aqueous hydrochloric acid: indeed, an ounce or two of chloride of arsenic may readily be prepared by adding an equal bulk of strong oil of vitriol to such a solution. It is not so pure, however, as that obtained from the aqueous solution of chloride of arsenic, and must be rectified if required in a state of purity.

4. *Chloro-arsenite of Ammonia.*—The aqueous solution of chloride of arsenic is mixed with strong liquid hydrochloric acid in sufficient quantity to prevent the formation of chloro-arsenious acid, and a small lump of chloride of ammonium is introduced. At first, small, hard, reddish-coloured, cubical crystals, consisting of almost pure chloride of ammonium, make their appearance; but after some days, long fibrous needles of snow-white colour and pearly lustre begin to form, and gradually fill up the liquid. These consist of the salt under consideration. They are well-drained, and dried by pressure between folds of blotting-paper. The following results were obtained with the salt dried over oil of vitriol:—

Arsenic	32·23	1= 75	32·12
Ammonium	15·23	2= 36	15·42
Chlorine	44·78	3=106·5	45·61
Oxygen	..	2= 16	6·85
		233·5	100·00

The formula of the dry salt is therefore $2NH^4Cl, AsClO^2$. The loss of water by exposure over oil of vitriol amounted to 4·27 per cent.; one equivalent of water gives 3·71 per cent. During the desiccation, a little chlorine is evolved and replaced by oxygen.

I am still engaged in prosecuting the investigation of the compounds of chloro-arsenious acid with the metallic chlorides, and in endeavouring to form corresponding acids containing iodine and bromine.

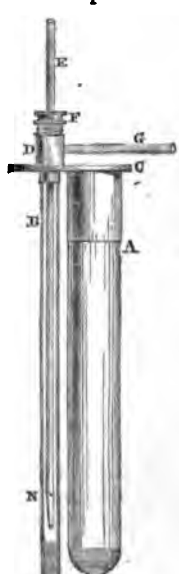
Observations on Dry Collodion Processes. *By* W. S. Ward, *F.C.S.*

On the Source of Ammonia in Volcanic Emanation. *By* R. Warington, *F.C.S.*

At the Meeting of the British Association at Liverpool, 1854, the author demonstrated the existence, in the lavas of Vulcano, of nitride of boron, which by the action of watery vapour is converted into boracic acid and ammonia. Adopting an analogous reasoning, he considered that, in volcanic districts where hydrated silicic acid and ammonia were the ordinary products, a similar compound of silicon and nitrogen should be met with. On examining the Pelagonites from the Hecla district, the author finds that they always contain nitrogen in combination, as he believes, with silicon as a nitride of silicon, and that the source of ammonia in volcanic phenomena may be principally attributed to the action of aqueous vapour, at high temperatures, on this compound.

On an Instrument for maintaining a Water-Bath at constant Temperatures. *By* John Waterhouse, *F.R.S.*

The author exhibited to the Chemical Section an instrument which he called a "Thermostadt," the object of which he explained to be, to afford the means of keeping a water-bath at a uniform and unvarying temperature for an indefinite period. In the accompanying sketch, A B is a glass tube bent upon itself, and when filled with spirit or other expansible fluid, forming a thermometer of large dimensions: the two ends of this tube are cemented into the brass cap and plate C, the end A being hermetically closed, and B open; D is a stuffing-box (into which the open end of the tube is cemented), through which the tube E, open at both ends, passes, and which may be fixed in any required position by the tightening screw collar F; to the upper end of this tube is attached a flexible tube, which may be connected with an ordinary gas-pipe; G is a small tube screwed into the side of the stuffing-box D, and communicating with the tube B or stem of the thermometer, and serves as an attachment for another flexible pipe which connects the apparatus with the burners which are placed under the water-bath. A small quantity of mercury, M, is introduced to separate the spirit in A from the open stem of the thermometer B. The operation of the instrument is as follows:—the whole being immersed to the plate C in the water-bath, the gas passes through E into the tube B, and thence through G to the burners; as the temperature rises, the spirit expands, and causes the mercury to rise in B until it finally closes the terminal aperture of the tube E, when the gas ceases to flow; to prevent, however, the total extinction of the flame, which would now take place, a small hole, N, is pierced with a needle through the side of the tube E at about an inch from the end, which allows a sufficiency of gas to pass to support a speck of flame not larger than a large pin's head. In operation the flame soon acquires its appropriate dimensions to keep the bath at a perfectly steady temperature, the exact amount of which is determined by sliding the tube E in its collar, and thus giving the mercury a greater or less range.



At first a difficulty presented itself in procuring a burner of sufficiently small aperture for the jet, which would not be liable to be stopped up by the oily deposit from common coal-gas; this, however, was completely removed by making burners of ordinary pipeclay, piercing them with a fine needle, drying, and then making them red-hot in a common fire.

The instrument in this state had been in constant use for seven or eight years, during which it had been chiefly employed to regulate a small apparatus for carrying on a series of experiments on incubation, and its steadiness of action had proved to be all that could be desired. The author mentioned to the Section as one proof of its utility in such investigations, that it had enabled him to prove clearly the evolution of vital heat in the process of hatching eggs, which are shown to acquire a temperature for some days before the completion of their incubation, several degrees above the atmosphere in which they are placed; a fact, which he believed had not been verified by actual experiment, though it would naturally be anticipated. The author stated that the contrivance was the joint production of himself and Mr. S. Smith of Halifax.

GEOLOGY.

Address by WILLIAM HOPKINS, *M.A., F.R.S., President of the Section.*

THE President, in opening the Section, proceeded to observe:—the existence of mammalian life in its earlier stages on the surface of our planet, the conditions of its existence, and the period of its introduction, have always furnished questions of the highest philosophical as well as palæontological interest. You will be aware that some geologists regard each new discovery of mammalian remains, in formations preceding the older tertiaries, as a fresh indication of the probable existence of mammalia in those earlier periods in which no positive proof of their existence has yet been obtained; while others regard such discoveries only as leading us to an ultimate limit, which will hereafter define a period of the introduction of mammalia on the surface of the earth, long posterior to that of the first introduction of animal life. Be this as it may, every new discovery of the former existence of this highest class of animals must be a matter of great geological interest. An important discovery of this kind has recently been made, principally by the persevering exertions of Mr. Beckles, who has detected in the Purbeck beds a considerable number of the remains of small mammals. The whole of them are, I believe, in the hands of our President, Mr. Owen, for the determination of their generic and specific characters; but Dr. Falconer seems already to have recognized among them seven or eight distinct genera, some of them marsupial, and others probably placental, of the insectivorous order. I may also notice, as a matter of great palæontological interest, the recent discovery of a new ossiferous cave, near Brixham, in Devonshire, of which some account is to be brought before us during this meeting. The past year has been fruitful in palæontological researches, but it is not my purpose to notice them in detail.

I proceed to one or two points of interest in the physical department of our science. The internal structure of rock masses, with reference to joints, planes of cleavage, and crystallization, is a subject of great interest to those who would study the operation of physical causes in producing all the modifications of state through which the matter now forming the outer crust of the globe must have passed in the lapse of geological time. A considerable number of observations have been made by different geologists respecting the positions of the planes of joints and of cleavage, but I confess myself little satisfied with any laws of the phenomena unless deduced from observations of far greater accuracy of detail than that by which these observations have generally been characterized. I allude more particularly to this subject, because some progress has, I think, been made in the mechanical explanation of a part of these phenomena, those which relate to the laminated cleavage structure. Direct experiments have been made by Mr. Sorby and Dr. Tyndall, which leave no doubt of the possibility of producing this structure by direct pressure alone; and in certain simple cases, in which the divisional planes form a system of parallel laminæ, this mechanical cause may be sufficient to account for the phenomena. But in many other cases in which there appear to be several systems of these planes of structure, the positions of which would seem to bear determinate relations to each other, it would appear extremely difficult to account for the phenomena by the simple operation of pressure alone. It is likely, I conceive, that more complicated causes have been at work, though pressure may have exercised an important influence. Again, it has been suggested that what has been termed the force of shrinkage, or that internal tension which may be produced in extended masses by their contraction from the loss of heat or moisture, might be sufficient to account for the formation of joints, the positions of which, you will recollect, approximate more or less to verticality. But there is one curious feature in these phenomena, which appears to me inexplicable on this theory. It is well known that in conglomerate formations in which large boulders are imbedded, the joints pass completely through the boulders without any apparent interruption. According to this theory, these boulders must have been pulled in two by the force of shrinkage. It is in this that the difficulty I allude to consists; for it would appear, I think, extremely difficult to conceive how the general matrix of such a conglomerate, whatever may be the force with which it contracts, should obtain a sufficiently powerful grasp on the two opposite halves of a smooth and rounded boulder, a few inches in diameter, to pull them asunder. I suspect in all these phenomena the working of some agencies more refined than those of simple compression and extension.

The subject of the motion of glaciers is one of interest to geologists; for unless we understand the causes of such motion, it will be impossible for us to assign to former glaciers their proper degree of efficiency in the transport of erratic blocks, and to distinguish between the effects of glacial and of floating ice, and those of powerful currents. An important step has recently been made in this subject by the application of a discovery made by Mr. Faraday a few years ago, that if one lump of ice be laid upon another, the contiguous surfaces being sufficiently smooth to ensure perfect contact, the two pieces in a short time will become firmly frozen together into one continuous transparent mass, although the temperature of the atmosphere in which they are placed be many degrees above the freezing temperature. Dr. Tyndall has the merit of applying this fact to the explanation of certain glacial phenomena. There are two recognized ways in which the motion of a glacier takes place—one by the sliding of the whole glacial mass over the bed of the valley in which it exists, and the other by the whole mass changing its form in consequence of the pressures and tensions to which it is subjected. The former mode of progression is that recognized by the sliding theory; the second is that recognized by what has been termed the viscous theory of Prof. Forbes. The viscous theory appeared to be generally recognized. Still, to many persons it seemed difficult to reconcile the property of viscosity with the fragility and apparent inflexibility and inextensibility of ice itself. On the other hand, if this property of viscosity, or something of the kind, were denied, how could we account for the fact of the different fragments into which a glacier is frequently broken, becoming again united into one continuous mass? Dr. Tyndall has, I conceive, solved the difficulty. Glacial ice, unlike a viscous mass, will bear very little extension. It breaks and cracks suddenly; but the separate pieces, when subsequently squeezed together, again become by regelation (as it is termed) one continuous mass.

After some general remarks on the cause of the laminar structure of glaciers, he remarked that there was no doubt Dr. Tyndall was right in supposing the laminæ of blue and white ice to be perpendicular to the directions of maximum pressure. He reminded the Section, that he had himself shown this fourteen years ago, by a rigorous mathematical investigation of the internal pressures and tensions of the glacial mass, resulting from the more rapid motion in its central than in its lateral portions; and the results of this investigation were entirely sanctioned by the experimental elucidations which Dr. Tyndall had given of the nature of these internal pressures. The physical explanation of the formation of the veins could scarcely yet be regarded as complete; but the actual perpendicularity of the laminæ of ice to the directions of maximum pressure within a glacier, and the probable perpendicularity to those directions of the laminæ in rock masses of laminated structure, would seem to establish some relation between these structures in rocks and glacial ice, giving an interest to this peculiar structure in the latter case, which it might not otherwise appear to possess for one who should regard it merely as a geologist.

He concluded his remarks by referring to the papers to be read before the Section.

On the Fossil Fishes and Yellow Sandstone. *By the* Rev. Dr. Anderson, *Newburgh.*

Referring to his paper in the Report of the British Association of 1850, the author remarked that much discussion had since occurred as to the true *position* and *formation* of the Yellow Sandstone of Dura Den, as well as of other localities. It was termed the *Yellow* Sandstone, not simply because of the colour generally, but because of its striking contrast with the other members of the Old Red Sandstone series*. In Ireland it seems to be regarded by Sir Richard Griffith, in his valuable communication to the Section last year at Dublin, as holding a doubtful position, whether relatively to the Old Red or to the Carboniferous system. Mr. Jukes declared, on the same occasion, his conviction that "the whole fish-beds of Scotland, and the similar rocks in Glamorganshire and South Wales, might belong to the Carboniferous system." This confusion arose, the author was persuaded, from the confusion in the rocks themselves in these localities, where, through means of the intrusive traps, they are all upheaved and disturbed in their positions and relations to each other. But in Dura Den the whole series are in the closest juxtaposition, and to be read off with the ease of letter-press from sectional descriptions. He had further to add, upon the question of age and position, that no *Pterichthys* nor *Pamphractus* had been found in any of the rocks immediately above the yellow deposit of Dura Den, and he challenged the detection of one of either genus from any of the strata yielding *Cephalaspis* or the grey sandstone beds with *Pterygotus* beneath, in Forfarshire, Perthshire, or Caithness. *Diplopteri* were likewise abundant in this deposit. Sir Roderick Murchison and Lord Kinnaird had accompanied him, a few days ago, to Dura Den, and he was now fortified in his conclusion by the high authority of Sir Roderick, who at this Sectional Meeting has declared "that there could be no doubt whatever that the yellow sandstones of Fifeshire pertain truly to the Old Red group, are entirely subjacent to the lowest carboniferous sandstones, and are of the same age as the upper yellow sandstones of Elgin."

"The sectional drawings on the wall exhibit in the closest relation the wonders of the two geologic ages, the Carboniferous and the Old Red. A step carries you from the one series of rocks to the other. A vast, universal, inconceivable change passes over the surface of the globe; the seas in greater varieties and in multiplied forms of marine life; the land all over abounding in trees and fern-forms of the amplest dimensions; and leaping across the stream, in this narrow dell, you pass the shadowy bourn which separates two of the oldest and most remarkable epochs in the world's history. The mighty operation is marked on a small scale, though recorded in the most legible characters; a slight depression in the dip of the strata on the one side of the rill, a few black lines interspersed among the stripes of white rock on the other side; and this is the simple lithograph by which Nature tells of energies whose products are mountains and valleys, new teeming lands, seas swarming with the moving thing that hath life, and mineral treasures enclosed for man's use and comfort which Time only can exhaust†!"

Passing from this point, now, he thought, completely established, the author of the paper proceeded to a description of the fossils so abundant in the deposit, amounting to four genera and seven or eight distinct species of fishes and crustacea. The beautiful drawing of the large specimen before them was that of a *Holoptychius nobilissimus*, excavated last week from its stony bed of ages, and adding a new member to the Dura Den family of the genus, and thus placing it higher in the series than the rocks of Glashbennie, or those of Cromartie and other localities in the north. He held in his hand a specimen of the two bones of the head termed the *glosso-hyal* plates that supported the lower jaw, and which resembled very much the plates in the existing *Sudis gigas* of the American rivers. The huge Megalichthys of our Scottish coal-fields had three *glosso-hyal* supporters, as if Nature in her arrangements had made size a condition of organic structure. Upon the whole, he concluded, we have in Dura Den a classic field for geologists of the deepest interest; much has been obtained, much remains to be detected in future researches. For the general

* Course of Creation, by Dr. Anderson, p. 57. Longman, Brown and Co., London.
† The author's 'Geology of Scotland.' Pictorial History. Virtue and Co., London.

student, it was a chapter in the earth's history, over which may be inscribed in the most legible characters, "Science made easy," so well defined are the rocks of the several systems, and so distinct and remarkable are the organic remains by which they are classified and filled to repletion.

On the Volcanoes of Central Asia, commencing with the Baikal, in Oriental Siberia, and extending into Mongolia and Chinese Tartary, illustrated by a beautiful series of drawings of the principal volcanic scenes described. By T. W. ATKINSON, *F.G.S.*

The author said he did not intend to furnish a strictly geological account, describing each stratum and mass of lava scientifically, his desire being only to point out and describe volcanic regions passed through in his travels, commencing with that round the Baikal in Oriental Siberia, and continuing to the Syan-shan; extending over a country lying between 80° and 110° east longitude, and from 41° to 55° north latitude, and embracing a great variety of steppe and mountain, including a part of the desert of Gobi.

The Baikal had by some persons been considered a vast crater, of which wonderful stories were told by those who inhabit its shores. It was said to be nearly 600 miles in length, varying from 30 to 40 miles in width. The northern shores of the Baikal were rocky, and rose from 500 to 600 feet above the water, and, in a few places, there were steppes or planes down to the water's edge. The island of Olchon stretches along the northern shore; it is about 60 miles in length, and from 12 to 15 miles in breadth. There was no appearance of volcanoes ever having been in action either on the northern shore or on the island. On the southern shore, near Tourkniskaia and Bargouzin, volcanic action had most undoubtedly taken place.

He next described the Kosso-gol, a lake 75 miles in length and 22 in breadth, bounded on the north and west by snow-capped mountains; on the lower slopes were several volcanic domes from which lava had issued. Nearly in the middle of the lake there was a conical-shaped island, probably 300 yards in diameter, and from 250 to 300 feet high. This he also believed to be volcanic.

In the valley of the Oka, which was 120 miles to the westward, he came upon a bed of lava more than a mile in width, extending nearly across the valley. The lava had a metallic appearance, and was very hard. As he proceeded along the valley, the lava increased in thickness; in some places it rose up like a wall 40 feet high, and in others it was heaped into enormous masses, and with great chasms crossed the bed, as if formed by the mass in cooling. He then detailed his exertions to discover the source of this stream of lava, during which he found that there had been two other eruptions; the first had added to the old another stratum of lava 24 feet thick; the second a bed of 35 feet thick and a mile in breadth. The description of what happened to the expedition in search of the source of the lava was exceedingly interesting. After a five days' journey the crater was reached; its length was 2 miles, and three-quarters of a mile in width. It was after many long and weary rides, extending over more than 500 miles, into Chinese Tartary, that he reached a singular dome-shaped hill, near which he discovered a bed of lava. On examining the spot, he was assured that the substance had gushed from several places on the side of the mount, and had run a short distance down the ravine. He determined to ascend the dome and examine the summit. The whole mass was of a dark purple-grey colour, with the appearance of having been forced up in a soft or fluid state into the shape of an enormous air-bubble. It was split and fractured in every direction, but not in regular strata. That this was the commencement of a volcano was quite certain, but the molten matter must have found an outlet elsewhere. There was not a blade of grass or moss growing on the dome, to the summit of which he and a Cossack scrambled with great toil and difficulty. The distance from this place to Pe-shan, a volcano still in action, is about 450 miles.

On the Fructification of Cyclopteris Hibernica (Forbes), *from the Upper Devonian or Lower Carboniferous Strata at Kiltorkan Hill, County Kilkenny. By* W. H. BAILY, *F.G.S.*

Mr. Baily in a few short notes alluded to this beautiful and well-preserved fossil fern, named by Prof. Edward Forbes *Cyclopteris Hibernica**, and obtained in such great profusion from the Upper Devonian or base of the Carboniferous system at Kiltorkan Hill, County Kilkenny, as having received additional interest from the discovery of several specimens exhibiting it in various stages of fructification, and illustrating other parts of its structure, forming part of a large collection recently made by the Geological Survey from that locality.

A diagram illustrating these particulars was exhibited and explained, including, first, what was considered to be the base of the stem or rhizoma, having a rounded expansion, apparently separating into scales, which continued upwards, fragments of leaflets being attached to the stem at different intervals. The venation of a leaflet, from one of the principal pinnules, presented longitudinally arranged striæ which were occasionally forked.

One of the fertile pinnules of a specimen showed the spores were aggregated into clusters or sori, and that the indusium or protecting cover had been but little broken up. A fertile pinnule from another specimen, however, appeared to be in a more advanced stage, losing in a great measure the aggregated character of the sori, and showing the protecting cases (which were granulated) to be much disturbed.

Other specimens in the collection were alluded to; one of which, with a length of 16 inches, had twelve pinnules on each side of the rachis in full fructification, without any appearance of leaflets, the spore-cases being scattered in all directions; another, of the same length, had about twenty pinnules on each side, the lower ones being in full fructification, which decreased gradually towards the upper portion of the frond, the leaflets taking its place.

Mr. Baily, having visited the locality, found the ferns to be most numerously distributed through the beds which were composed of a fine-grained compact greenish yellow sandstone, readily splitting into thin layers, some specimens presenting an appearance of irregular venation and distortion as if from softening or maceration in water: associated with them were many other plants and specimens of a large freshwater bivalve, *Anodonta Jukesii* (Forbes), having both valves united. About 3 feet from the surface, in a much coarser and more irregular sandstone not splitting into laminæ, numerous fish remains were collected, believed to be the osseous plates of *Coccosteus* (like *C. decipiens*), and with them a single tooth of a Sauroid fish, probably *Dendrodus*, being the second specimen of that kind obtained from this locality.

The beds were found to dip at a very slight angle, about four or five degrees to the S.W., having angular joints, in the neighbourhood of which they were much broken up.

The section exposed was stated to be as follows:—

No. 1. A superficial deposit from 18 inches to 2 feet, with broken fragments containing the same plants as in the beds beneath.

No. 2. Fine-grained greenish shale with *Cyclopteris* and other plants, 1 foot.

No. 3. Coarser sandy bed not splitting into layers, with *Coccosteus*, and few plants, 1 foot.

No. 4. Fine-grained sandy shale, with *Cyclopteris* and other plants, splitting into layers, the lower beds being coarse, and the *Cyclopteris* large but not well-preserved.

On two new species of Crustacea (Bellinurus, König*) from the Coal Measures in Queen's County, Ireland; and some Remarks on forms allied to them. By* W. H. Baily, *F.G.S., and of the Geological Survey of Ireland.*

The peculiar Coal-measure Crustacea, described by Mr. Baily, were first discovered by Mr. George Henry Kinahan of the Geological Survey of Ireland, at the Bilboa Colliery, Queen's Co., in debris obtained from the three-foot bed of shale immediately over the coal, associated with a few plants and numerous small bivalve shells (*Myacites*) allied to *Unio*, together with others of the Mytiloid form (*Myalina*); the deposits in which they occur, like those of Coalbrook Dale, from which the allied forms were first obtained, being of freshwater or estuarine origin.

Mr. Baily alluded to a paper, previously read before the Geological Society of

* Exhibited by the late Professor Forbes at the Meeting of the British Association at Belfast in 1852.

Dublin, on one of the specimens first discovered, which he proposed should, as well as the allied and probably contemporaneous forms found in ironstone nodules from the Penney stone of the lower coal-measures, Coalbrook Dale, hitherto included in the genus *Limulus*, be removed from the recent genus, as presenting characters more closely allied to Trilobites, and to which new genus the name of *Steropis* was given. Since then, however, more perfect specimens and another species had been obtained by himself and Mr. Kinahan, which had still further confirmed his views respecting the necessity for a rearrangement of the genus; and as one of the most common species was originally figured by König in his 'Icones Sectiles' in 1825, by the name of *Bellinurus bellulus*, he considered it but just to restore that generic name in preference to adding a new one. These Coal-measure Crustacea appearing to be the commencement of the Limuloid type, it was thought advisable to consider them as a subgenus of *Limulus* under the name of *Bellinurus*.

The nomenclature would therefore be the following:—

Order ENTOMOSTRACA.

Legion Pœcilopoda. Order *Xiphosura*.

Genus *Limulus*, Müller; subgenus *Bellinurus*, König.

Bellinurus (*Limulus*) *anthrax*, Prestwich, Geol. Trans. 2nd ser. 5. t. 41. f. 1–4. Coal-measures, Coalbrook Dale.

Bellinurus (*Limulus*) *rotundus*, Prestwich, Geol. Trans. 2nd ser. 5. t. 41. f. 5–7. Coal-measures, Coalbrook Dale.

Bellinurus (*Limulus*) *trilobitoides*, Prestwich, Geol. Trans. 2nd ser. 5. t. 41. f. 8; and Buckland, Bridgw. Treat. p. 396. t. 46″. f. 3. Coal-measures, Coalbrook Dale.

Also Col. Portlock, Report on Londonderry, &c. t. 24. f. 11, doubtfully referred to this species.

Synonyms of this species—(*Entomolithus monoculus*), Martin, Pet. Derb. t. 45. f. 4. (*Bellinurus bellulus*), König, Icon. Sect. pl. 18. No. 230.

[In Parkinson's 'Organic Remains,' vol. iii. pl. 17, a similar fossil is said to be figured from Dudley: *vide* Buckl. Bridgw. Treat.]

Bellinurus Regina, Baily, n. sp. Coal-measures, Bilboa Colliery, Queen's Co.

Bellinurus arcuatus, Baily, n. sp. Coal-measures, Bilboa Colliery, Queen's Co.

Descriptions of these two new species were given by Mr. Baily; *Bellinurus Regina*, which was of small size, being remarkable for having had the cephalic shield and thoracic rings extended into long spines; these diminished in regular gradation towards the tail, which was small and bore a spine of great size and length, being three times that of the animal.

Length 1 inch and $\frac{1}{20}$th. Breadth $\frac{1}{2}$ inch and $\frac{3}{20}$ths. Length of tail-spine $\frac{16}{20}$ths of an inch.

The second species, *Bellinurus arcuatus*, was said to be allied to *B. trilobitoides*, but differed in its general form and the greater spreading out of the spines at the posterior angles of the cephalic shield; also in the development of two additional spines from the ridge of the glabella extending over the body.

Several specimens of this species were obtained; one from a concretion in the shale exhibited the form of the body, which was broadly ovate and acuminated posteriorly, having a moderately developed tail-spine; it showed distinctly the division of each thoracic ring into segments, having grooved lateral angles, as in the Trilobites.

Length 1 inch. Breadth $\frac{18}{20}$ths of an inch. Length of tail-spine about $\frac{1}{2}$ an inch.

Mr. Baily then alluded to the great palæontological interest attached to the discovery in Ireland of new forms of Coal-measure Crustacea so similar in character to those found at Coalbrook Dale, Shropshire, by extending their distribution to corresponding strata in that country, and indicating similar conditions to have been prevalent over a wide area.

On a comparison of these Coal-measure Crustacea with the more recent and living forms, the wide gap in point of time corresponds with the great difference observable in their structure, which exhibits a closer alliance with the Trilobites. On the contrary, there is a striking resemblance between the Upper Jurassic remains, which are those of true Limuli and the living forms.

On the Yorkshire Flagstones and their Fossils. By W. Baines.

In illustration of the origin of this rock, the author relates the following observations. On a bleak moor side, in the shelving formation of a fine sandstone, was a hollow dammed across for the accumulation of rain-water for scouring purposes. In a few years it was filled up by a gradual deposit of sand. When dug out, there were presented finely laminated strata. In noticing other depositions, the author found that each layer was the deposit of one shower; and in proportion to the quantity or time of each succeeding rain, did the thickness of the deposit depend: each layer is the effect of one flood, a time intervening when the sand was all accumulated at the bottom, and the water had smoothed its surface by a very gentle action; so that the smoothed bed would not allow of the next flood's deposit to mix.

The laminæ of the rock may be as thin as paper, or 1 inch thick for roofing-slate, or 2 or 3 inches thick, which is the Yorkshire flag, or an uninterrupted deposition of ages, when it becomes the cutting stone or ashlar, a number of square yards in one mass without any cleavage. This Yorkshire flag then is but the pond deposit above noticed on a larger scale, and the deposit of some ancient estuary whose waters washed the finer particles of the carboniferous sandstone from the Halifax and Todmorden districts; but the deposition must have taken place, if not in deep water, certainly in still water; for the smallest, yea, the faintest breeze of wind, caused the ripple-marks, as thousands of the freestone slabs show, in the strata overlying the flag formation, and the uppermost strata must have been formed in shallow water, and at times completely dry, as there are hundreds of acres which bear impressions of rain or hail drops having impinged upon the strata in process of formation. There are great quantities of the tracks and depositions of annelides, or, as they are locally termed, the earthworm. It is a formation extremely barren of animal remains.

The Flora in the Yorkshire flag is not so numerous as in the ragged or crooked stone above and below, simply from its being a quieter deposit than the other strata. The most common fossil found in this formation and its kindred shale is the Calamite, some shales between the different strata being literally composed of its impressions. The next most common plant is the *Stigmaria* in profuse abundance, but very rarely the trunk or Sigillaria. It is quite evident that the tuberous appendages denote it to be a mud plant or roots. Some of the most magnificent and perfect specimens of the *Lepidodendron* are found in this strata. There are also *Pecopteris nervosa* and *Neuropteris*, &c.; as also a few fossil fruits, similar to *Trigonocarpum ovatum*.

Only two seams of coal, namely, Halifax soft and hard beds, lie under this stratum, and above the great millstone grit base; while thirty-three beds or bands of coal, with hundreds of varying strata, overlie this deposit within twenty miles eastward to Old Normanton, forming a series over 700 yards deep.

On the Atlas and Axis of the Plesiosaurus. By L. Barrett, *F.G.S.*

In a young specimen of *Plesiosaurus* presented to the Geological Museum of the University of Cambridge by Thomas Hawkins, Esq., the atlas and axis have not coalesced, and are detached from the remainder of the cervical series. The axis is nearly entire; but the atlas has lost part of its posterior articular surface, and the whole of the second subvertebral wedge-bone. The interesting unanchylosed condition of the four bones composing the atlantal cup is a sufficient excuse for occupying a small portion of the time of the Section with a comparison of these bones with those described by Prof. Owen in the 'Annals of Natural History' for 1847, and the corresponding parts of the skeleton of the new species of *Plesiosaurus* described by Prof. Huxley in the last number of the Geological Journal.

We will first consider the structure of this specimen. The four bones composing the atlantal cup have been slightly displaced; and its shape is a little altered. The base of the neural canal is formed anteriorly partly by its centrum and partly by the expanded bases of the neurapophyses; posteriorly the centrum is much larger, and forms the entire base of the canal. The upper thirds of the neurapophyses are much expanded and bent backwards; their inner angles have not coalesced, and there is no trace of a neural spine. The anterior surfaces of the lower part of the neurapophyses are concave, and form the antero-lateral segments of the articular cup for the occipital condyle; laterally their inferior edges slightly overlap the first wedge-bone; posteriorly they thin away, exposing the postero-lateral edges of the centrum.

That part of the centrum which forms the middle of the upper half of the atlantal cup is hexagonal, and it has a small pit in its centre; posteriorly its articular face is three times as great (nearly as large as the articular surface of the body of the axis), and has a circular depression in the middle. The wedge-bone forms the lower half of the articular cup, and has been produced behind into two long processes, the bases of which only remain.

The neural spine of the axis is long, and much thicker than that of any of the succeeding cervical vertebræ; the apex is broken off in this specimen. The neurapophyses are separated from the centrum by a distinct suture; and an oblique ridge connects on each side the anterior with the posterior zygapophysis. The antero-inferior edge of the axis is bevelled-off, forming an articular surface for the second wedge-bone; and the basal portions of two cervical ribs remain attached to the anterior lower part of the centrum: they must have partly articulated with the second wedge-bone.

The axis of *Plesiosaurus Etheridgii*, lately examined by Prof. Huxley, agrees entirely with that of this species; but there are some important modifications in the structure of the atlas.

Prof. Huxley describes the atlantal cup in this species as being divided by a tri-radiate mark into three portions—one inferior and two lateral and superior. The inferior piece corresponds with the lower half of the atlantal cup, or the anterior sub-vertebral wedge-bone; and the two supero-lateral pieces, with the neurapophyses in the specimen first described; but their bases are much more developed.

There is a small circular bone in the centre, which Prof. Huxley considers to belong to the os odontoideum; it is the anterior articular face of that bone, and corresponds to the hexagonal bone in the middle of the upper half of the atlantal cup in the former species,—the difference in position being caused in this species by the great development of the supero-lateral pieces or bases of the neurapophyses.

The postero-lateral edges of this bone are greatly developed, forming a rounded ridge on both sides of the posterior part of the atlas: the extraordinary development of this part of the bone is the most remarkable feature in the atlas and axis of this species.

We now come to the species first described by Prof. Owen. We have two specimens, in the Woodwardian Museum, of this species, both from the Kimmeridge Clay of Haddenham, near Ely; the larger of the two was figured by Prof. Owen in the 'Annals of Natural History,' vol. xx.

The neural arches in both specimens are broken away; and the bodies of the two vertebræ have so coalesced, that the original line of separation is scarcely visible. The neurapophyses and cervical ribs of the axis have become anchylosed to the bodies of that vertebra. The posterior half of the bottom of the neural canal in the atlas is formed by the true centrum of that vertebra; but in the anterior half the bases of the neurapophyses have spread over the centrum, and have united at the medial line. On the upper part of the atlantal cup, a groove indicates the position of the original suture between the bases of the neurapophyses and the lower part of the atlantal cup. In the larger specimen there is a trace of the suture which separated the anterior subvertebral wedge-bone from the upper part of the atlas, but which is absent in the smaller specimen.

In the atlas of the three species of *Plesiosaurus* we have now considered, the anterior articular face of the atlas is made up of four bones: of these, the os odontoideum is the most variable in size. Prof. Owen correctly assigned to it a large share in the formation of the atlantal cup in the Kimmeridge Clay species. It forms about a third of the upper half of the cup in the young unanchylosed specimen, and in *P. Etheridgii* is extremely small. Its position varies: in the young specimen it forms the base of the neural canal of the atlas; in the Kimmeridge Clay species it is overlapped by the expanded bases of the neurapophyses; and in *P. Etheridgii* it occupies the centre of the cup. The bases of the neurapophyses of the atlas are most developed in this species, and least in the Kimmeridge Clay species; in all cases the anterior subvertebral wedge-bone forms a large portion of the atlantal cup. That the suture between this bone and the os odontoideum, in the atlas of the species figured by Prof. Owen in the 'Annals' for 1847, is correct, we have abundant proof in the structure of the atlas of *Pliosaurus*, where the os odontoideum is of exactly the same shape, and the wedge-bone separated from it by a similar suture.

It is remarkable that the Kimmeridge Clay species approaches more nearly the Ichthyosaurian type than the Lias species, not only in the greater development of the os odontoideum and in its lateral edges forming the lateral margins of the atlas, but in its supporting the neurapophyses; there is really no essential difference between the atlas of this species and the atlas of *Ichthyosaurus*.

The atlas of *P. Etheridgii* and that above referred to, as figured by Prof. Owen, show many Crocodilian affinities (the neurapophyses being supported both by the wedge-bone and the centrum); but the posterior edge of the centrum does not support a pair of ribs (plurapophyses), and no trace of ribs articulating with the wedge-bone has been discovered. The second vertebra of the same species supports cervical ribs articulated to its body; but in all other respects it resembles that of the Crocodile.

On the Marine Shell Bed of the South Wales Coal Basin, showing the presence of Vegetable Remains in the Upper Coal Measures of the District, and of Shells and Fish in the Lower Coal Measures, and illustrating the continuity of forms of life in different stratifications. By G. P. Bevan, *M.D., F.G.S.*

The South Wales basin occupies two great divisions—upper and lower measures—chemically divided into bituminous and anthracite, the latter principally in Carmarthenshire and Western Glamorganshire; Pennant rock series principally at Swansea. Average thickness of lower beds of coal, 47 feet; total thickness of arenaceous and argillaceous strata, 1500 feet. In this we have seven or eight zones of animal life:—1st. Farewell Rock, lying on the millstone grit, which I propose to name Rosser Rock: there are thin seams of coal in this rock containing a bed of marine shells, which I have traced for fifty miles; from this bed I have obtained forty-three varieties. 2nd. Above this is the bottom vein of coal, containing fish remains and *Spirifer bisulcatus*. 3rd. The blue vein, with *Anthracosia*, *Modiolopsis* and *Spirorbis*. 4th. Red vein, with *Cardiomorpha*. 5th. Old coal, with *Unio*, *Modiola*, and traces of Crustaceans. 6th. Daren Pins, with *Myalina quadrata* and *Unio centralis*. 7th. Bydellog coal, with *Athyris planosulcata*, and at Pontypool, *Productus scabriculus*. 8th. Three-quarter coal, with *Terebratula hastata* and Mountain Limestone species at 700 feet above the Carboniferous Limestone. 9th. Ellid, ferns. 10th. Black Pins, *Unio aquilinus*. 11th. Soap vein, shell uncertain.

On the Vegetable Structure visible in the Coal of Nova Scotia. By Professor Dawson, *of Montreal.*

Photographs of Quarries near Penrhyn, showing the structure of Granite. By John S. Enys, *F.G.S.*

Remarks on certain Vermiform Fossils found in the Mountain Limestone Districts of the North of England. By Albany Hancock.

After a full description of some peculiar crustacean tunnels or tracks observed on the sandy shores of Northumberland and Durham, the author of this paper examines in detail certain vermiform fossils obtained in the fine-grained, micaceous sandstones of Haltwhistle, Wensleydale, and Pateley Bridge. These curious fossils, of which there are two principal forms, one grooved, the other nodulous, had hitherto been considered to be the remains of worms, or of worm-tubes, or the casts of worm-tracks; but the author objects to this opinion, on account of their great size, their dissimilarity to worms, or tubes or tracks of worms; and because certain characters exhibited by the fossils themselves preclude the idea of an organic origin. He states, however, that they are undoubtedly tracks originally, as now, composed of the same material as the slabs upon which they rest; and the high probability that they were formed by Crustaceans is deduced from the remarkable correspondence of their characters to those of the runs or tunnels of these animals, as observed by him on our northern shores.

Having arrived at this conclusion, it is then suggested that these fossil tracks may have been produced by Trilobites, which agree very well in size with them. The largest tracks of the grooved form are a little above an inch wide. The width of the pygidium of *Phillipsia truncatula*, a carboniferous species, is 11 lines, that of the cephalic shield would probably be a little more; therefore if allowance be made for the thickness of the tunnel wall of the burrow or track, and the necessary enlargement of the calibre beyond the width of the animal, it is evident that, so far as the size is concerned, the largest tracks might be attributed to this species.

The nodulous tracks are stated to be not more than half an inch wide; there can therefore, be no difficulty as to size with respect to this form, for several species of Trilobites are described to be about that size. And in conclusion it is remarked that the large cephalic shield with its anterior or head-tubercle (glabella) and projecting "cover of the eyes," appears well calculated to plough its way beneath the surface of the sandy or muddy beach.

Burmeister, indeed, in his work on the 'Organization of Trilobites,' published by the Ray Society, expresses an opinion that their habits, like their structure, resembled those of the *Phyllopoda* (a tribe of the Entomostraca), and that they "moved only by swimming in an inverted position close beneath the surface of the water, and did not creep about at the bottom as Klöden supposed." Though their habits may have been similar to those of the *Phyllopoda*, there does not seem any good reason for asserting that there was no deviation in this respect. In fact, the organization of the two groups differs in so many particulars, that some variation in their modes of life might naturally be looked for. The Trilobites may have occasionally swum at the surface as supposed, and also have burrowed in the mud or sand at the bottom of the water or on the beach. Season, too, may have modified their habits in these respects.

On the Distortion of Fossils. By Professor Harkness, *F.G.S.*

On the Origin of the Breccias of the Southern Portion of the Valley of the Nith, Scotland. By Professor Harkness, *F.G.S.*

The southern portion of the Vale of the Nith consists of deposits of the Permian age, capable of being divided into three groups. The lowest is composed of sandstones which afford footprints, the middle of thick breccias, and the upper of red sandstone. The middle member is for the most part made up of *angular* fragments, which have been derived from the Silurian strata surrounding the Permian area. Besides these angular Silurian fragments, portions of red porphyries also occur in these breccias, and these portions of porphyries have an equally *angular* character with the Silurian fragments.

The porphyritic pieces which are imbedded in these rocks have no representatives in the form of rocks of porphyry nearer than about twenty miles from the localities where they present themselves; and no ordinary action of water is able to account for their occurrence in an *angular* condition among the constituents of the breccias of this locality.

Professor Ramsay has described the angular transported fragments which form the Permian breccias of Worcestershire and Shropshire (Quart. Journ. Geol. Soc. vol. xi. p. 185 *et seq*). In these breccias the fragments have their surfaces, in many instances, well marked by grooves and striæ, and they possess many features which have induced Professor Ramsay to regard the breccias of these counties as having resulted from the agency of ice, leading to the inference that Arctic conditions prevailed during a portion of the Permian epoch.

The deposits which, in the southern portion of the Vale of the Nith, are composed of angular fragments, do not bear about them the same features in the form of grooves and striæ which characterise the breccias described by Professor Ramsay. The angular nature of the fragments, and the distance which some of them have been transported, justify the conclusion that transport by water has not been the agent which gave rise to these breccias; and as no other force capable of transporting *angular* fragments a considerable distance at present operates except ice, it becomes necessary to refer the presence of these breccias to the same cause which gave rise to those of Worcestershire and Shropshire. The absence of the grooves and striæ from the fragments which compose the Dumfriesshire breccias, indicates that the mode of operation of the ice was somewhat different in these from those occurring in Worcestershire and Shropshire. Glaciers seem to have had their influence in producing the deposits in the latter areas, whilst in the former the ice seems to have acted principally as a raft, transporting rocky fragments from one area to another. The circumstances which the breccias of the southern portion of the Vale of the Nith present, seem to justify the conclusion of Professor Ramsay, that glacial conditions obtained during part of the Permian epoch.

Observations on the Genus Pteraspis. *By* THOMAS H. HUXLEY, *F.R.S., Professor of Natural History, Government School of Mines.*

In a paper "On *Cephalaspis* and *Pteraspis*," recently read before the Geological Society, and published in the 'Quarterly Journal' for the present year, I endeavoured to prove,—

1st. That the *Cephalaspis Lloydii* and *Lewisii* of the author of the 'Recherches sur les Poissons Fossiles,' subsequently united into a distinct genus, *Pteraspis* (Kner), were rightly judged by Prof. Agassiz to be the remains of fish, and that they are not, as had been imagined by other naturalists, either Crustacean or Molluscan.

2nd. That, as Prof. Agassiz had surmised, they are at once allied to *Cephalaspis*, and generically distinct from it.

I grounded these conclusions almost wholly on histological evidence, or that afforded by the microscopic structure of the bodies in question. Not having seen the *Cephalaspis rostratus* of Agassiz, I abstained from offering any opinion with regard to it.

Since the publication of my paper a great deal of new material has passed into my hands, chiefly by the kindness of the zealous geologists and palæontologists who reside in and about Ludlow, Messrs. Cocking, Crouch, Harley, Lightbody, Marston, and Salwey, and I have thereby been enabled greatly to extend and confirm my conclusions with regard to the nature and affinities of these remarkable extinct fishes. A brief note of the results at which I have now arrived will perhaps be interesting to the Section.

The oblong plates which have hitherto been the only discovered parts of *Pteraspis*, form only a portion of the great shield which covered the anterior part of the dorsal region of the body. Apparently anchylosed or continuous with the anterior edges of some specimens of these plates, there is a bony disk, prolonged at its postero-lateral angles into two long cornua, which pass into the edges of the oblong plate. The disk exhibits the characteristic structure and the peculiar striated sculpture; it is prolonged anteriorly into a sort of rostrum, whose length varies with the species of *Pteraspis*: laterally it exhibits two well-marked nearly circular marginal apertures, which I make no doubt are the orbits.

I conceive, therefore, that the part in question corresponds with the anterior part of the cephalic disk of *Cephalaspis*, and that the oblong plate, which may well be termed the occipito-nuchal plate, answers partly to the posterior moiety of the cephalic disk of *Cephalaspis*, partly to that median backward prolongation of the posterior margin of the cephalic disk of *Cephalaspis* to which I have particularly directed attention in my memoir. It is from this that the strong nuchal spine of the *Cephalaspis* arises; and as if to render the resemblance complete, the most perfect specimens of *Pteraspis* show that it had a like spine developed in a similar position.

There exists, indeed, a most interesting gradational series of forms between *Cephalaspis Lyellii* and *Pteraspis*.

The *Auchenaspis* of Sir Philip Egerton has a cephalic disk with the semicircular anterior outline of that of *Ceph. Lyellii*, but the interspace between the cornua of the disk is nearly filled up by the large nuchal plate, whose backward extent may have been greater than is exhibited by any of the specimens of *Auchenaspis* yet obtained. Enlarge the nuchal plate of *Auchenaspis* and give the cephalic disk a more produced anterior outline, and the result is the form of *Pteraspis*.

Throughout all these gradations of form, however, it must be borne in mind that the minute structure of the parts is such as at once to enable the observer to distinguish *Cephalaspis* from *Pteraspis*.

I ventured in my paper read before the Geological Society, to say that the Ganoid nature of *Cephalaspis* and *Pteraspis* appeared to me to be unproved, and to allude to the relations between these genera and the great group of existing *Siluroidei*. Without at all wishing to push too far resemblances which, when we come to know more, may turn out to be mere analogies, I must say that the new facts which I have brought forward appear to point somewhat in the same direction. The siluroid fishes, in fact, are especially characterized by the large bony nuchal plate which supports the great dorsal spine, and is constantly anchylosed to the posterior margin of the skull. The rostrum of the *Pteraspis* is not without its analogue in *Loricaria*.

On the other hand, that rostrum might be compared with the prolonged snout of *Acipenser*; and the shield of *Pteraspis* presents many points of similarity with the cephalic buckler of such fishes as *Dipterus*, *Diplopterus*, and *Osteolepis*.

On the Jointed Structure of Rocks, particularly as developed in several places in Ireland. By Professor William King, *F.G.S., Queen's College, Galway.*

The author, adverting in the first place to the view which he advanced at the Dublin Meeting on the so-called slaty cleavage in its *perfect* state, that it is the combined effect of jointing, and of pressure exerted more or less perpendicularly to its planes, stated, that he had since visited several localities in Mayo, Galway, Clare, Limerick, Tipperary, Kerry, and Cork, and had obtained a number of important data fully bearing out his view. His researches had also afforded him much insight into jointing—a divisional structure of more importance in Physical Geology, he thinks, than appears to be generally understood. The author then proceeded to describe jointing as it occurs in the Carboniferous limestones of Galway and Clare. In these counties there may be made out four distinct sets of joints, two of which, from being east or west (the number of degrees varying) of compass north, he terms—one, *east meridional*, and the other, *west meridional*; while the remaining two, which more or less rectangle the former, he designates—one, *east equatorial*, and the other, *south equatorial*. The east meridional set is the strongest and most regular: it runs in an undeviating course for miles and miles, generally from N.N.E. to S.S.W.; plains, valleys and mountains being all alike affected by it. In many places it cuts the limestone into plates from half an inch to little more than an inch in thickness; a circumstance, favouring the idea, that, under proper conditions, jointing may be developed to the utmost possible extent. None of the other three sets is so well developed; the south equatorial, which runs a few degrees south of west, is with some difficulty made out. In consideration of the various phenomena which occurred to him, he has formed the conclusion, that only horizontal or undisturbed beds exhibit the original or normal direction of the joints with any certainty; and considering that the beds which have the east meridional set running N.N.E. and S.S.W. are horizontal, he concludes that such is the normal bearing of this set; and he further assumes, that any deviation from such direction has been caused by disturbances of the strata. Entertaining these views, he applies them in elucidating and reconciling certain complicated and seeming discordant phenomena; showing that some highly inclined beds, striking east and west, like the limestones of Cork, may have one of their sets of equatorial jointing lying horizontally; while in others, having only their basset edges exposed on the surface, the vertical and not the horizontal direction of the joints is exhibited. Assuming the principal jointing in Yorkshire, Derbyshire, Devonshire, and other counties to run generally from N.N.W. to S.S.E., as stated by Phillips, Hopkins, De la Beche and others, he regards the west meridional as the dominant set in England. This difference in direction between English and Irish jointing is analogous to what occasionally obtains in the Dingle peninsula; and a difference still more striking occurs within a space of a few yards or so, in a (Silurian) bed on the shore of Lough Mask. In connexion with the close approximation of the joints, as rather frequently displayed in the Carboniferous limestone of the West of Ireland, attention was directed to that form of divisional structure in coal, known as cleat, and which has often been regarded as a sort of crystallization; the author, however, from various facts and reasonings, is decidedly of opinion that it is nothing but jointing in a state of extreme development. Notwithstanding cleat being sometimes, as in *pure* coal, apparently as illimitable as mineral cleavage is in calcite or fluor-spar, the author contends, that in ordinary coal it is undistinguishable from the approximate jointing of many ancient argillaceous deposits. The paper concluded by some observations on the so-called slaty cleavage in the brown and purple shales of Cork: Professor King considers it as highly developed or *cleat-like* jointing, belonging to one of the equatorial sets, and having had its planes forced into a nearly vertical position by pressure exerted in a particular direction when the beds were thrown into their present anticlinal and synclinal rolls: he considers that the pressure was not sufficient to produce any other structural modification, or in other words, that it was insufficient to bring the divisional planes in immediate contact, as in *true* slate rocks; hence the Cork shales generally are not *illimitably* cleavable, as is the case with the former.

On the Geology of the Lake District, in reference especially to the Metamorphic and Igneous Rocks. By J. G. MARSHALL, *F.G.S.*

I propose in the present paper to confine my observations to the Cambrian and older Silurian rocks of the Lake District, below the Coniston limestone; consisting of an alternating series of igneous and sedimentary strata, all of which have been more or less acted upon by central heat.

I shall endeavour to show that the phenomena observed may be best explained by the supposition, that the whole series of rocks, granites included, are metamorphic sedimentary strata, *in situ*, or in their natural order of position; and that the slaty rocks alternating with the porphyries are to be accounted for on the supposition that they are by chemical composition less fusible, less easily acted upon by heat, than the porphyritic beds, and have therefore been only hardened, retaining their cleavage and stratified structure, whilst the more fusible rocks have been changed into porphyries.

The two oldest rock formations of the Lake District, the clay-slate of Skiddaw and Saddleback, and the greenstone slate of Helvellyn and Scaw Fell, have, as is well known, the usual north-east and south-west strike and south-east dip of the rocks of the same age in Wales and Scotland. It is evident also that the district occupied by them includes an anticlinal axis, for we find the greenstone slate on the northern and north-west border of the clay-slate, as at Binsey, at the foot of Bassenthwaite, dipping north or north-west. The first step in describing the physical structure of the district will therefore be to ascertain the position of this anticlinal axis. I believe that this point has not yet been completely or satisfactorily made out, and it was the first object of my recent walks over this country to gain some fresh light on the subject. There is perhaps no great geological interest attached to the ascertainment of this point, considered as an isolated fact; but considered in reference to the inquiry into the relation of the granites of this district to the sedimentary rocks, it is of some importance.

This inquiry into the correlation of granite and its accompanying metamorphic rocks with the sedimentary strata, whose age is known by their organic remains, has only lately attracted much notice from geologists. The vast labour of ascertaining the true age and order of superposition of the whole range of sedimentary rocks chiefly by their organic remains, had to be first accomplished. Accordingly we find that Sedgwick, in his description of this district, has not entered into the question at length or in detail. In his letters to Mr. Wordsworth, he gives a section, which he is careful, however, to tell us is only an ideal or explanatory, not an actual section of the rocks of the district, showing their order of superposition. Here the Skiddaw granite is placed at the base of the series of rocks, and in the anticlinal axis of the district. This, though professedly only a provisional section, is one remarkable instance, with innumerable others, of the very general disposition amongst geologists, to assume tacitly that the origin and position of granite in the order of superposition of rocks is peculiar,—quite distinct from that of all sedimentary strata. Accordingly the granite apparently at the base of the clay-slate would be assumed to be in its normal position, or at any rate more nearly so than the Eskdale and Shap Fells granites which appear amongst the higher beds of the greenstone slate. These latter, together with the Ennerdale syenites, would be assumed to be eruptive,—to have had their origin far below their present position, and to have been forced up in a melted state. It has been one principal object of my recent examination of this district, to ascertain whether the facts bear out this prevailing conception as to the origin and position of granite, or not.

It is of some importance, as one step in this inquiry, to ascertain whether or not the Skiddaw granite is found in the anticlinal axis of the district.

At the last Meeting of this Association at Dublin, Prof. Harkness read a paper on the geology of the Caldbeck Fells, and gave a section through Saddleback, the Syning-Gill granite, and Caldbeck Fells, showing that the powerful greenstone dyke or dykes which run through Caldbeck Fells, are the true anticlinal axis of this part of the district, and not the granite. Both Prof. Phillips and the late Daniel Sharpe have given sections through the whole range of Skiddaw to the foot of Bassenthwaite, showing a continued series of beds of clay-slate all dipping at about an angle of 35° or 40° to the south-east. In all these particulars my own observations agree with the descriptions previously given by these observers.

But though there seems to be no doubt that the Caldbeck Fells, running nearly east and west, and having the greenstone slate strata on their northern bank plunging down at high angles with a dip nearly north, but a little to the west of south, is the *actual* anticlinal of the eastern portion of the Lake District, it cannot be considered as the *normal* anticlinal even of this portion of the district; for the dip of the strata of Skiddaw and Saddleback is uniformly to the south-east, agreeing with the general dip and strike of the whole district, and not with the strike of Caldbeck Fells. Hence we must conclude that the fracture of the strata and igneous outburst of greenstone dykes which accompanied the elevation of Caldbeck Fells, was of *later date* than the original elevation of the rocks of this district and the formation of the anticlinal, which must have accompanied that elevation.

We must look then for the original or normal anticlinal in the western part of the district. The dip of the clay-slate in Whinlatter and Wythop Fells is south-east nearly as far as the foot of Bassenthwaite. Here the beds of clay-slate may be seen thrown into arches and much contracted; and in Sale Fell indications of a reversal of dip to the north-west begin to appear. But the strata at this point are much confused by the intrusion of greenstone dykes and the proximity of the line of the Caldbeck fault, which runs westward to a point near Cockermouth, crossing the line of the original anticlinal.

The clay-slate in the mountains about Crummock Water and to the east of the Vale of Lorton, have all the south-easterly dip. But in the range of hills to the west of the Vale of Lorton I found a decided and regular anticlinal or reversal of dip, which may be seen distinctly on the northern shore of Loweswater and in Revelin on the southern shore of Ennerdale Water: in both cases the dip is W.N.W., about 10° or 15°. We may consider a line drawn from near the foot of Bassenthwaite through Loweswater and the foot of Ennerdale Water, as the original or true anticlinal of the Lake District, and that the upheaval along the line of Caldbeck Fells which completes the north-western boundary is of subsequent date. The angle formed by the Caldbeck fault with the Ennerdale and Loweswater anticlinal, is the first indication of the action of those forces, which by their complicated action have so dislocated the strata of the Lake District. If we look to its south-eastern border, which is so distinctly marked by the Coniston limestone, we shall see that the line from the head of Windermere to Shap Fells granite is nearly parallel to the Caldbeck Fells fault, and makes a considerable angle with the direction of the western part of the southern boundary, showing that the strike of the whole of the beds in the eastern part of the district has been twisted out of its original direction. I shall have occasion to revert to this fact when I am endeavouring to trace the nature and direction of the elevating forces which have raised up the strata.

I now proceed to describe what appeared to me to be the relative position of the granite to the overlying slate rocks at the three points where it is seen in the Lake country.

The appearance of the grey granite of Skiddaw at Syning Gill in the valley of the

Calder, between Saddleback and the Caldbeck Fells, and the gradual transition in the beds above it from glossy clay-slate to chiastolite slate, hornblende slate and gneiss immediately in contact with the granite, have been so often and so well described, that I must not repeat what is already known. What was material to my present purpose to observe was, that the granite seemed to me to comport itself in all respects as if it were simply another term in the series of metamorphic changes following the gneiss.

The general dip of the beds of clay-slate in Skiddaw and to the westward is about 40° to the south-east. In the northern flank of Saddleback, and near the point where the granite appears, this dip has increased to 60°; in the bed of the Calder, at the foot of Caldbeck Fells, I observed it about 80°; and in the hills above it seems to have become nearly vertical where any dip or stratification can be made out. The point in Syning Gill, on the northern slope of Saddleback where the granite appears, is very little above the level of the bottom of the valley. The granite occupies the bottom of the valley, and rises up the southern slope of the Caldbeck Fells to a considerably higher elevation than that of Syning Gill,—perhaps 200 or 300 feet above the valley.

The upper boundary of the granite is therefore a line dipping to the south-east, but at a lower angle than that of the beds of clay-slate, and cutting obliquely across them. If we suppose the clay-slate to have had originally the general dip of 40° before the elevation of the Caldbeck Fells fault tilted them up to a higher angle, then the upper boundary of the granite would have been nearly horizontal, representing the isothermal line of igneous fusion; and we should have the beds of clay-slate dipping towards and into this line, and converted into granite as they passed below it*. No veins of any importance have been observed penetrating from the granite into the rocks above, nor did I see any other indication of this granite having been eruptive or intrusive, or having in any way disturbed the overlying strata.

The Skiddaw granite is found, as we have seen, amongst the middle or lower beds of the clay-slate formation. We next find granite amongst the lower beds of the greenstone slate formation in Eskdale and Miterdale; and this is by much the most extensive granitic region.

In order to explain the position of this Eskdale granite, I must first describe the remarkable geological position of Black Comb and the range of hills forming the eastern boundary of Eskdale. Black Comb is a huge isolated mass of clay-slate 2000 feet thick, heaved up amongst the highest of the greenstone slate series of rocks, having the Coniston limestone immediately upon its south-eastern flank. What is the relation of the clay-slate to the greenstone slate beds? Is it cut off on all sides abruptly by great faults; or have the neighbouring greenstone beds been raised along with it, and do they rest conformably upon it? What is the relation of the clay-slate to the granite? Is there any evidence that the granite either underlies the clay-slate or else is distinctly eruptive?

It was my object, in a recent examination of the Black Comb range, to find an answer to these questions. I found the central mass of Black Comb dipping nearly due north about 20°. On the western and eastern flanks of the mountain the dip becomes north-west and north-east respectively. I found the same dip in direction and amount in the whole of the ridge of greenstone slate running continuous with Black Comb, as far at least as Devock Water, to which point I more particularly observed it. These greenstone slate beds seemed to me to be clearly the lower coarse conglomerate slates and porphyries of that formation. The actual junction of these rocks with the clay-slate is generally covered up; but the clay-slate and coarse greenstone slate may be seen in the course of a stream crossing the road from Bootle over Stoneside Fell, within 20 yards of each other and clearly quite conformable in dip, and the character of each rock as perfectly distinct as if they had been found miles apart. I found these lower greenstone slate beds completely wrapping round the north-western border of the clay-slate as far as Bootle, as shown in Sedgwick's map. These rocks dip north-west or *towards* the granite, and distinctly separate it from the

* If this line is continued underneath Saddleback southwards, it will very nearly indicate the position of the syenite at the foot of St. John's Vale, an igneous rock appearing amongst the *higher* beds of the clay-slate.

clay-slate. On the eastern flank of Black Comb I found the same beds of coarse greenstone slate wrapping round the clay-slate, and separated from the upper beds of finer roofing-slate by a line of fault running north and south, and nearly following a road running from Beck Bank on to Stoneside Fell. On the south-western border of Black Comb the new red sandstone comes up to the clay-slate.

It appears then, if my observations are correct, that the Black Comb range on the east of Eskdale consists of an axis of elevation running north and south, and which has elevated both the clay-slate and the lower beds of the greenstone slate in conformable position; and that the latter have a north-westerly dip *towards* the *granite* in the lower part of the valley. As we have the same lower beds of the greenstone slate in the range of the Screes on the south-east of Wast Water dipping towards the south-east, there seems good evidence to conclude that Eskdale and Miterdale, taken together, may be considered as a broad synclinal valley subdivided by subordinate anticlinal ridges. We must then consider this as a great valley of denudation, exposing the granite in its lower parts, and Scaw Fell and the other lofty mountains at its head, consisting of the setting on of the higher beds of the great greenstone slate formation.

It remains to be ascertained whether the granite is eruptive and intrusive, or metamorphic, in the latter case consisting of the lower beds of the greenstone slate, which lying at the bottom of a trough, have been more exposed than the neighbouring strata to the central heat, and also have been more deeply covered up.

I think all the direct evidence on the spot is strongly in favour of the latter supposition. Sedgwick, who examined this district with great care many years ago, states that the granite is everywhere bordered by a belt of transition metamorphic rocks, by which it appears to graduate into the greenstone slate.

These transition beds between the greenstone slate and granite may be well observed in the course of the stream running from Devock Water into the Esk, and also under the Screes at the foot of Wast Water.

The unaltered rocks in the hills about Devock Water consist of a bluish grey felstone porphyry, with small crystals of quartz or hornblende. The first change on approaching the granite is that this rock loses its porphyritic character, and becomes a very dark, almost black compact greenstone. The next change is to a soft crumbling rock, with an entire change of colour to various shades of red, yellow, or pinkish grey; after this, finally, a transition through several varieties of quartzoze and crystalline rock to compact crystalline granite. In the Eskdale granite the mica is very commonly wanting or replaced by hornblende.

The thickness of these transition beds is various. Under the Screes they did not seem to me to occupy more than 60 or 80 feet; but near Devock Water between 200 and 300 feet.

An important point to be observed here is, whether the upper limit of the granite is on the whole conformable to the dip of the greenstone strata above it. The whole of the Screes is so hardened by heat and so shattered, that it is difficult to ascertain the dip of small portions, though the whole mass evidently has an easterly dip. The line of soft metamorphic rocks marking the upper limit of the granite is seen near the foot of Wast Water, apparently running quite conformably under the beds of greenstone slate of Screes. The position of the granite near Burnmoor Tarn, at the foot of Scaw Fell, is also quite analogous to that at Devock Water.

I think I may be justified in saying that the direct evidence to be obtained on the spot, in the case both of the Skiddaw and of the Eskdale granite, is in favour of their metamorphic character. It will make my argument more clear and intelligible, if I proceed to notice in the same manner the direct evidence to be obtained by observation upon the spot, as it appeared to me at the time, in the case of the other igneous rocks of the district, the syenite of Ennerdale, and the granite of Shap Fells, before I inquire what objections may be raised to this hypothesis, and what may be alleged for or against the contrary hypothesis, that these igneous rocks are not metamorphic, but eruptive and intrusive.

The syenite of Ennerdale occupies an intermediate position, as is seen upon the map, between the clay-slate and the greenstone slate. Is it an intrusive eruptive rock, or is it metamorphic, consisting of some of the upper beds of the clay-slate changed into syenite?

I followed its boundary from Seatoller under the mountain Hay Cock, Steeple, and Pillar, to the point where it crosses the Liza river in Ennerdale.

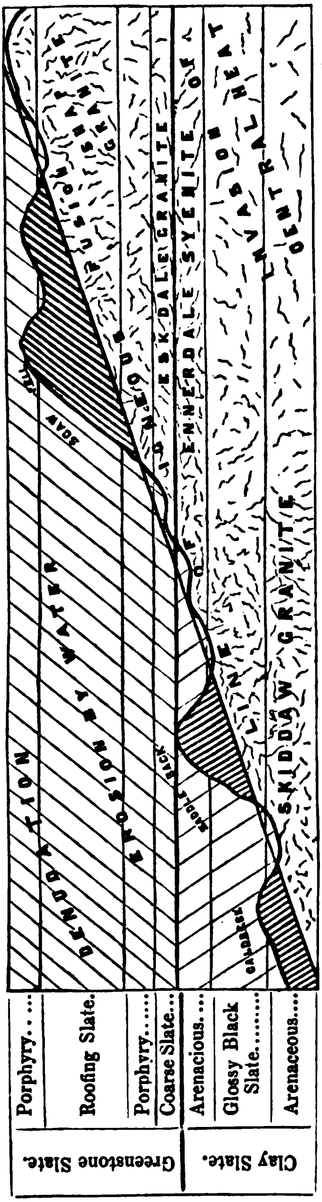
The greenstone beds here consist of the coarse conglomerate slate similar to those resting on the flanks of Black Comb: the general dip is to the south-east. There is a similar border of transition rocks between the clay-slate and the syenite, to that between the same rock and the granite, a nearly black greenstone and beds of softened rock, but they are less regular and less considerable. I followed the upper limit of the syenite as it descends the southern side of Ennerdale under Pillar, and it seemed to me to be on the whole conformable to the beds of greenstone slate resting upon it: so also on the northern side of the valley, the syenite is seen ranging under the greenstone slate of High Stile. About half-way down Ennerdale Water the clay-slate appears with a south-east dip underlying the syenite. In the western flank of Revelin, the mountain on the southern bank at the foot of the lake, the dip of the strata is distinctly W.N.W. at an angle of about 10°, whilst the dip on the eastern flank of the same hill near the syenite is south-east; thus the principal anticlinal of the district is shown to pass through the middle of Revelin. I found the W.N.W. dip also at a corresponding point on the south side of the lake, in a gill at Crosslands. The strata on the northern side of Ennerdale, between Floutarn Tarn and Red Pike, are much broken up and confused by faults and entanglements of masses of the clay-slate in the syenite, as described by Sedgwick.

On the whole, the direct evidence to be obtained on the spot seemed to me to be in favour of the supposition that the syenite is metamorphic, consisting of the upper bed of the clay-slate. I may mention, as confirming this opinion, that the transition beds of syenite in Ennerdale contain the same crystals of Chiastolite, which are such a distinguishing mark of the transition beds immediately above the Skiddaw granite. In support of this hypothesis, I may observe that syenite in mass is found near Keswick in St. John's Vale, in a position exactly similar to that of Ennerdale; that is, immediately under the lowest beds of the greenstone slate. If this hypothesis is correct, the syenite must lie below the Eskdale granite, which I suppose to consist of the lower beds of the greenstone slate; and the position of the mass of syenite on the northern bank of Wast Water is quite consistent with that supposition, as the general dip of the strata is to the south-east.

The only remaining area of igneous rock which I have to notice is that of the Shap Fell granite. This granite is very limited in extent, though very decidedly marked in character, and so well known by its boulders scattered far and wide by the northern drift. It constitutes the end of a range of rough porphyritic rock which immediately underlies the Coniston limestone through its entire course, and which here passes under the mountain limestone belt which encircles the Lake mountains on their eastern border. All the neighbouring rocks are much indurated and altered by heat. In approaching the granite from the west, the Coniston limestone is lost, and the flagstone above it much altered for some miles in extent. The granite has evidently been in a highly fluid state, and has extensively penetrated the adjoining slate rocks in ramifying veins. But I saw no evidence of any great faults or other disturbance of the natural order of the strata; and in the absence of this evidence, the only conclusion I could arrive at was, that this granite also is metamorphic, consisting of the highest bed of the greenstone slate, viz. the rough porphyry immediately underlying the Coniston lime.

I have now completed the direct evidence to be obtained on the spot as to the relative position of the granites and slate rocks, and I must proceed to notice the difficulties and objections which may be made to the metamorphic hypothesis. How can we account for this metamorphic action of the central heat having been produced at such very different depths in the series of strata, from the lower beds of the Skiddaw slate to the highest of the greenstone series?

I think this may be explained on the simple supposition that the strata were already *inclined* before the metamorphic change took place. We must take into account also the much greater denudation of superincumbent strata which we know takes place in some localities, than is observed in others. Combining these two postulates, I think we may arrive at a fair solution of the difficulty. If we look at the map, we see that the Shap Fells granite occurs at the south-east corner of the district, just where the dip of the strata would carry the upper beds down the deepest, and where they would be most thickly covered by superincumbent strata, *since denuded*. The Eskdale granite is next in order, then the syenite, and lastly the Skiddaw granite. We may fairly suppose the inclination of the strata to have been such, that all these points may have been buried to the same depth, and equally reached the line of igneous fusion. I have endeavoured to illustrate this by a section.



General Ideal Section.

Another objection may, however, be taken. It may be said, "Why is not the belt of syenite, represented to be the upper beds of clay-slate, become metamorphic, continuous along the whole border of the clay-slate, instead of only appearing at Ennerdale and at St. John's Vale, near Keswick?"

I think this difficulty may be fairly met by the supposition that a cross line of elevation, running along the high range of mountains between Crummock and Keswick lakes, may have existed *before* the metamorphic action took place, and thus the intervening rocks may have been raised above the lines of igneous fusion. In the same way we may, I think, fairly suppose that the Black Comb axis of elevation may have existed *before* the metamorphic action which produced the Eskdale granite. Again, it may be objected that the fragments and masses of slate rocks entangled within the adjacent igneous rocks, as in the case of the clay-slate and syenite in Ennerdale, so graphically described by Sedgwick, is a proof of the violent intrusion or eruptive character of the syenite. But if it can be shown, as I shall endeavour to do afterwards, that the fractures and upheavals of the strata are due to general causes quite distinct from and independent of the presence of igneous rocks, then this entanglement of fragments simply proves the igneous rock to have been fluid, and is no argument against its metamorphic character.

I will now proceed to notice some of the objections which may be made to the opposite hypothesis to that I have been advocating, viz. the supposition that these granites are eruptive and intrusive, not metamorphic.

I exclude, of course, the supposition that these different granitic areas can be portions of a granitic base common to all the stratified rocks and irregularly exposed by denudation only; for in that case we should have the whole thickness of the clay-slate interposed between the Eskdale granite and the greenstone slate, whereas not a particle is to be seen.

If the granite has been erupted in a fluid state, it is difficult to imagine how it could occupy such broad spaces as in Eskdale, except by flowing over the adjacent strata. I think all the evidence of observation on the spot contradicts this supposition.

If the granite, on the other hand, were brought up in a solid state in mass, then it must be bounded by faults. I think no geologist can look at the sinuous irregular outline of these granitic areas, and suppose for a moment that these boundaries are great faults lifting up the strata some 5000 or 10,000 feet.

Again, if these granites and syenites were all eruptive from some unknown depth common to all of them, it would be difficult to account for the distinct and separate type or character which each possesses.

I venture to come to the general conclusion, therefore, that both positive and negative evidence favours the hypothesis, that the whole phenomena of the granitic and igneous rocks of the Lake District are a grand and very interesting exhibition of metamorphic action on a large scale. I feel that there is still a difficulty remaining which will occur to most of us. We have been accustomed to look to the violent eruption of those igneous masses as the *cause* of the upheaval, fractures, faults, and contortions of these mountain regions. Take away *this* cause, and what adequate causes have we left to which such effects can be attributed?

This inquiry would lead me to enter upon a subject of very high interest, but so wide and large in its bearings, that I feel it almost presumptuous in me to deal with it at all in such a presence as that I see round me. I may venture to give a mere outline of what has occurred to my own mind, which may serve as a starting-point to those much more competent than I am to treat of such a subject, and may at least afford some suggestions that may be worked out.

Since the time when Hutton and Playfair, Cuvier and Smith re-formed and re-founded, as it were, the theory of geology, the exertions of geologists have been chiefly directed to the completion of the vast labour of making out the stratigraphic order of position, and the accompanying series of organic remains of the whole stratified crust of the earth. It is only from time to time, and more especially of late years, and by no one more than by our present President, that the study of the Dynamics of Geology has occupied much attention.

It would seem that the progress of geology must shortly bring these questions much more prominently forward. The point to which I wish at present to draw attention, is the expansion and working out of some very remarkable and important suggestions first made by Babbage in 1834, and illustrated by Sir John Herschel in a letter to Sir C. Lyell, in 1836, on the causes which may have produced the elevation or submergence of continents. I must refer to the letter itself for a complete exposition of Sir J. Herschel's view; I can only now quote such portions as are immediately necessary to my argument.

The results arrived at appear to be:—

1. The transference of solid matter by abrasion from continents, and its deposit at the bottoms of oceans, disturb the equilibrium both of heat and pressure. The isothermal lines of internal heat will rise under the bottom of the ocean and fall under the continent; the strata under the ocean will be heated and thereby expanded, and thus the bottom will be raised. Again, the whole crust of the earth being supposed to be floating upon a fluid ocean of melted rock, the increase of weight in some parts and diminution in others will tend to crack or break the crust in its weakest parts.

2. These cracks or fractures, produced by general and constantly acting causes, will give rise to volcanic vents and earthquakes. Thus volcanic phenomena become of secondary importance; they are not the *causes* of the elevation of continents and mountain chains, but the *consequence* of such movements produced by far more general and constantly acting forces.

I may remark, that in all these speculations on the effects which the expansion of strata caused by the incursion of heat from below will produce, the expansion in a vertical direction alone has been adverted to.

But I think it is evident that the expansion which will take place in the bottom of an ocean 1000 or 2000 miles wide, will be very much greater in a horizontal or lateral direction than vertically, in the proportion which a length of 1000 miles bears to the thickness of 20 or 30 miles.

The enormous *lateral thrusts* which will be thus produced, seem to me to constitute an adequate dynamic force for producing those vast wave-like wrinkles and convolutions and tilting up and even inversion of strata which we see in mountain chains: for on the supposition that the bottom of the sea, subject to tension by expansion from heat, would give way at the weakest points, we are enabled to explain why these contortions of the strata should be accumulated on particular lines, and not generally distributed. They occur where the crust of the earth happens to have been weakest; and thus the whole effects of the expansion of 1000 miles of strata may be found within the compass of 100 or of 10 miles. If, then, we regard mountain chains generally as the convoluted and upturned edges of strata produced by enormous *lateral* pressure, I venture to think we shall approach much nearer to a true conception of the causes which have been at work, than in attributing such elevatory movement to perfectly vague and arbitrary volcanic forces. Another and a distinct cause has also been assigned for lateral pressure, which should throw the crust of the earth into wave-like elevations and depressions; viz. the contraction of the internal nucleus by cooling. The effects of the two causes would be similar, but the former would appear, I think, to be the more energetic and important.

I think the application of the principle, that the elevatory forces which raise mountain chains are to be looked for in *lateral thrusts*, will assist in forming a true conception of the forces which have dislocated the Lake District. Mr. Hopkins, our present President, has shown how the conformation of this district, the tendency in the valleys to converge towards a central point, may be in great part accounted for by the supposition that an elevatory force has acted on a line running nearly east and west from Shap Fells, through Helvellyn and Scaw Fell. The result would be a series of cracks or faults in the directions in which the valleys now run. This supposition I think accounts for a part of the phenomena, but not for the whole of them. A simple vertical force acting on the line supposed would neither account, I think, for the contortions of the strata in Shap Fells showing *lateral* pressure, for instance, nor for the fact that in all the valleys on the south of the line, the eastern side of the fault should be elevated, the western depressed. But if we observe that Shap Fells, the point where this line of elevation commences, is in the corner where the two great lines of the Pennine and Cross Fell faults meet at an angle, and suppose the elevatory force along this line to be the resultant of two *lateral* thrusts at right angles to these two great faults, I think we shall approach a true solution of the phenomena observed.

I cannot on the present occasion do more than dip into this most interesting and important department of Dynamic Geology; but I may perhaps have said enough to give a consistent meaning to my description of the geology of this portion of the Lake District.

It only remains for me to give some reasons for the supposition that the beds of porphyry interstratified in the greenstone slate series have been originally aqueous deposits changed into porphyry by metamorphic heat, combined with pressure, and the presence of water. It has been remarked long ago by Sedgwick, that the slaty and porphyritic beds of the greenstone slate formation are not separated or distinguishable from each other by any constant or clear characteristics. They run into each other almost indefinitely, both in passing across the strata from one bed to the next, and even in following the same bed along its line of bearing. This is sometimes shown in a striking manner in the weathered surfaces of the rocks. These surfaces may show externally all the marks of a stratified bed, the bedding, the joints, the cleavage, marked even by light-coloured stripes, and yet the first stroke of the hammer dispels the illusion; the rock is found to be a compact porphyry, which will not split according to the seeming external lines either of cleavage or joints. If any rocks are metamorphic, then these porphyritic beds have, I think, every external mark of being so.

I may here quote the words used by Sedgwick in his last work on Palæozoic Rocks. Speaking of the Cambrian greenstone slate formation, he says, "The modifications of the slate are first described, and it is shown that they pass on one hand into compact felspathic slate, sometimes porphyritic; on the other into coarse granular and concretionary slaty masses, and through them into breccias or pseudo-breccias; all these changes being effected without any change of strike or dip. In like manner it is shown that the amorphous, and even semicolumnar prismatic porphyries, are not only arranged in directions parallel to the tabular masses of green roofing-slate, but pass themselves into a slaty texture with a strike and dip parallel to those of the true roofing-slates. From these facts, as well as from the negative facts, that the porphyries never penetrate the roofing-slates in the form of dykes, and produce no mineral change in the beds of limestone resting on them, it is inferred that *the whole group is one formation, which has originated in the simultaneous action of aqueous and igneous causes long continued.*" Again, he maintains, "that many rocks, which now have a perfect porphyritic structure, were so far aqueous deposits, that they had been spread out into beds by the action of the sea, and that their actual structure (though certainly metamorphic) was not the effect of torrefaction or of heat emanating from any eruptive or igneous centre. On the contrary, that the natural temperature at great depths, combined with great pressure long continued, was a cause quite sufficient to explain the phenomena of the old stratified plutonic rocks."

The only important modification which I venture to propose in this statement is, that we must distinguish between the aqueous causes really simultaneous with the igneous; viz. the water or steam present in the rock when undergoing metamorphic changes at great depths by heat and pressure, and from the aqueous causes acting long before, when these beds were deposited as true rudimentary strata at the bottom of the ocean.

If the positive evidence, then, is strong in favour of these rocks being metamorphic, I think the negative evidence is not less so. In regions where igneous rocks abound which are clearly eruptive, we have many characteristic marks of their origin. They have a distinct mineral character and structure; they do not graduate into slaty rocks. We have distinct evidence of their overflowing neighbouring strata. We have distinct evidence of the manner of their eruption from below in the presence of many vertical dykes.

None of these phenomena are observed in the Lake District, as regards the porphyries alternating with the slates. The only difficulty to be accounted for, I think, is the great thickness of some of the slaty beds, which have remained unaltered whilst other beds above them have been changed by the action of the same heat into porphyry.

It is evident, that if the different beds can be shown to be of different degrees of fusibility, this circumstance would be at once accounted for; and I have made some experiments to test this point, and also on the effects of fusion and slow cooling in producing metamorphic effects upon rocks.

The first experiment was made for me by Mr. J. P. Wood, of Leeds, on clay-slate, greenstone porphyry, and greenstone roofing-slate, all reduced to fine powder, and about ¼ lb. of each placed in three crucibles in a common air-furnace, and gradually heated. At a good red heat the porphyry puffed up, fused, and ran over the edge of the crucible in the shape of a brown glassy slag; at a white heat the clay-slate fused into a grey glassy slag; and, lastly, at a strong white heat, the roofing-slate also fused into a black glassy slag. Thus the slate rocks appear to be decidedly less fusible; less easily acted upon by heat than the porphyries. The same result was obtained in fusing clay-slate, Skiddaw granite, and greenstone porphyry in a common reverberatory furnace; the stone being broken into pieces, about the size of those used for road-making, a white heat was required to fuse them, but the granite and porphyry melted much more readily and completely than the clay-slate. These simple experiments may be sufficient to prove a difference in the fusibility of the slaty and porphyritic beds, which would account for the latter undergoing changes by the same heat which would merely harden the former.

I next endeavoured to ascertain the effect of pressure combined with heat on the fusion of rocks, with the very able and zealous assistance of Messrs. Kitson and Hewitson, of this town. These experiments, which are attended with great difficulty, and require the patient endurance of a good many partial failures before a successful result can be obtained, are as yet only in progress.

Some results, however, may be seen in the specimens on the table.

The powdered granite, clay-slate, and porphyry were enclosed in strong iron tubes, well consolidated to begin with by hydraulic pressure, then screwed up and heated to a red heat in an air-furnace, and then slowly cooled.

The result is a compact mass of distinctly stony texture approaching to slaty greenstone, quite different from the porous glassy slags produced by fusion without pressure. The fusion has taken place at a lower temperature under pressure.

I next tried the effect of fusion of a large mass of granite, in this case from the Charnwood Forest in Leicestershire, which happened to be most easily procurable. This was done in a reverberatory furnace constructed for the purpose by Messrs. Kitson and Hewitson, but the accidental failure of a portion of the furnace in the course of the experiment partially spoiled the result. The specimens, however, show a distinct passage from a perfectly glassy to a stony texture, and apparently even to a porphyritic structure by the development of crystals.

There are also specimens of the glassy texture, which by exposure to heat just below fusion in close tubes for two or three weeks, are changed to a stony texture; also of the powdered rocks enclosed in a strong iron tube, and buried in the large mass of granite when in a state of fusion in the reverberatory furnace.

The great desideratum, however, is the application of heat under high pressure with the presence of water, which must have been the condition, as remarked by Sedgwick, of the metamorphic rocks. My attempts in this direction have not yet succeeded. It is no easy matter to construct any sort of vessel capable of keeping red-hot water in safe custody.

Photographs of the Quarry of Rowley Rag at Ponk Hill, Walsall. *By* WILLIAM MATHEWS, *F.G.S.*

The well-known basaltic capping of Ponk Hill in the South Staffordshire coal-field is being so rapidly worked away, that it has seemed desirable that some record of its structure should be preserved. With this view the photographs laid before the Section have been taken; they represent the whole of the face of rock now being quarried, from which the original structure of the mass may be easily ascertained. It formed when entire an irregular dome, communicating below with the extensive horizontal sheet of basalt intruded between the coal-measures, and consisted of two distinct sets of columns.

1st. An interior cylindrical group of very perfect vertical columns, rapidly thinning and arching over at the top some distance below the vertex of the dome.

2nd. Another group originating at the summit of the first, dipping down over their arched extremities, and then curving upwards so as to strike the exterior of the dome nearly perpendicular to its surface.

The columns are all situated in vertical planes passing approximately through the axis of the dome.

On Triassic Beds near Frome, and their Organic Remains. *By* C. MOORE, *F.G.S.*

The author stated he became aware of the probable presence of Triassic beds in the neighbourhood of Frome, by finding a slab of conglomerate containing teeth of *Acrodus*, *Hybodus*, and *Saurichthys* on a roadside heap of carboniferous limestone. He at once examined the district for their discovery without success; but more recently was fortunate enough to find fissures of the carboniferous limestone at Holwell, filled with a similar conglomerate, the organic remains in which evidenced its Triassic origin.

In describing the physical features of the district, the author remarked that Frome was situated on the extreme south-eastern boundary of the Somersetshire coal-field, and that just north of that town the old red sandstone, with a narrow belt of carboniferous limestone lying on its side, might be seen emerging from beneath the inferior oolite. To the west the carboniferous limestones again appear in several pretty combs leading to Mells, Vallis, and Whatley, in the latter of which the Holwell quarries are situated. In the quarry opposite this village the limestone is worked to a depth of 35 feet. A fissure about a foot in breadth, commencing under a thin capping of vegetable soil, may be here observed, taking an irregular direction to the bottom of the quarry, where it increases to 10 feet in breadth. This is in part filled with vertical laminæ of mottled yellow, grey and blue stone. A quartzose sand also prevails, sometimes indurated, but often friable; in which case, the imbedded organic remains may be readily detached.

First amongst these the Reptilia deserve notice, some of which belong to the Thecodont order which includes the *Thecodontosaurus* and *Palæosaurus*. Of the former, the author has obtained several teeth and vertebræ, and also several bony scutes or scales, which renders it probable one of the saurians of this period was covered with a bony armour like the *Teleosaurus* of the lias. These genera were originally described by Messrs. Riley and Stutchbury, from fragmentary specimens obtained from a conglomerate near Bristol, which has hitherto been considered to belong to the Permian period or to the dolomitic conglomerate, but from its precise lithological similarity to that of Holwell there can now be little doubt it belongs to the Triassic period. In referring to the absence of the Muschelkalk in this country, the author stated he had the pleasure of announcing, that, although the precise equivalent of that formation had not yet been satisfactorily made out, still in the presence of the teeth of another saurian—the *Placodus*—he had obtained the first indications of the fauna of that deposit being represented in England.

Important as were these indications of Reptilia, the fish remains from these conglomerates were probably of equal interest. They belong to the genera *Acrodus*, *Hybodus*, *Saurichthys*, *Lepidotus*, *Gyrolepis*, probably the *Ctenoptychius* or *Petalodus* of Owen, and some minute palates allied to *Chomatodus*, a genus not yet found higher than the carboniferous limestone. Teeth of the *Acrodus*, of several species, are very abundant, the next prevailing genus being the *Hybodus*. There are also some very peculiar thorn-like spines of not less than ten distinct varieties, belonging to some fish as yet undetermined, to the dermal coverings of which they were probably attached. So wonderfully preserved are some of these fish remains, that the author had been enabled to extract a jaw from the matrix, which, though not more than the eighth of an inch in length, contains all its teeth, thirty-four in number; and in another instance, a palate a quarter of an inch in length still retains seventy-four teeth, and shows blank spaces from which sixteen others had been lost.

The only evidence the author has yet obtained of regularly stratified Triassic beds is in the Vallis Vale, where there are several large quarries of carboniferous limestone, on the up-turned edges of which the inferior oolite lies horizontally, and is usually in immediate contact. This, however, is not the case in one near Hapsford Mills, where the following thin bands of Trias are found. Immediately on the carboniferous limestone, which is here quarried to the depth of 20 feet, occurs a bed of blue clay 4 inches in thickness, which yielded part of a Thecodont vertebra, fish remains identical with some from the Holwell conglomerate, and the teeth of several spines of *Acrodi* peculiar to this bed. It also yielded valves of *Chiton* and *Pollicipes*, with spines of *Pseudodiadema* and stems of encrinites, together with *Ostrea*, *Lima*, *Avicula*, and other shells. Succeeding this blue clay, is a bed of horizontal conglomerate 2 feet thick, made up of rounded pebbles, from the size of an egg downwards, and containing a few fish teeth and scales. Above is another band of blue clay 4 inches in thickness, passing into a grey concretionary clay 12 inches thick, neither of which has yielded any organic remains; and resting on these next succeed rubbly beds of inferior oolite, having a thickness of 12 feet.

Various other Mollusca have been obtained by the author from the beds above noticed, including *Spirifer*, *Terebratula*, *Rhynchonella*, *Lingula*, fragments of the large *Discina Townshendi*, which the author believed to be a triassic shell, *Pecten*, *Belemnite*, &c., and a single claw of a crustacean.

Note.—Since reading the above paper, it has been the author's good fortune to discover three unmistakeable *mammalian* teeth identical with the *Microlestes antiquus* of the Upper Trias of Wirtemberg, being the earliest evidence of mammalian remains yet found in this country.

Some Results of recent Researches among the Older Rocks of the Highlands of Scotland. *By* Sir R. I. MURCHISON, *F.R.S.*

The first part of the paper consisted chiefly of a confirmation and extension of views which the author had laid before the Geological Society in the preceding session. These views are, that the fundamental gneiss of the N.W. Highlands, being older than any stratified rock of England and Wales, is overlaid unconformably by sandstones and conglomerates of great thickness, which, occupying lofty mountains, represent the Cambrian rocks of South Britain; that these are surmounted transgressively by quartz rocks and limestones containing Lower Silurian fossils, or that the last are succeeded by micaceous schists and flagstones often passing into a younger gneiss.

The second part of the communication related to the Old Red Sandstone, properly so defined, as exhibited on the east coast, between the Orkney and Shetland Islands on the north, and Banffshire and Morayshire on the south, various points of which the author visited last summer. In Caithness and the Orkney Islands, accompanied by Mr. Peach, the author made various interesting additions to his former knowledge, and profited by the researches of Mr. Robert Dick of Thurso. His belief was sustained that the ichthyolitic flagstones of Caithness and the Orkneys, with their numerous fossil fishes, constitute the *central* member of the Old Red series, the lower part of which is made up of powerful conglomerates and a very great thickness of thin-bedded red sandstone, the whole being composed of the detritus of the more ancient crystalline rocks. The central flagstones are surmounted by other sandstones, rarely red, and usually of yellow colour, which occupy the promontories of Hoy Head, Dunnet Head, &c.

The chief additional data which had been gained by Sir Roderick during his last visit were owing, in the first instance, to a discovery by Mr. Martin of Elgin, of a large bone in the same beds at Lossie Mouth, which had formerly afforded large scales of the supposed fish, called Staganolepis by Agassiz. On visiting these quarries with the Rev. G. Gordon, he was so fortunate as to discover other portions of this large animal; so that comparative anatomists may determine whether it be, as the author believed, really reptilian. The existence of reptiles during the formation of this deposit is, indeed, established beyond a doubt; since many slabs have long been found in the coast quarries of Cummingston, in which are the footprints of both large and small reptiles, each footprint having the impression of four or five claws to it. A slab, transmitted by Capt. Brickenden, is in the Geological Society's Museum, and others have recently been sent to the Museum of Practical Geology, London, as contributions from Mr. P. Duff of Elgin, and other persons. The presence of large reptiles, as well as of the little Telerpeton, in a deposit which all geologists have hitherto considered to be an upper member of the Old Red Sandstone, is therefore established.

After noting certain fossil fishes which occur in parts of the Duke of Richmond's estates in Banffshire, the author proceeded to review the relations of the great masses of sedimentary deposit lying along the eastern and southern faces of the crystalline rocks of the Grampians, which have been hitherto classed as pertaining to the Old Red Sandstone, though he does not pretend as yet to be competent to describe their detailed features. On these points, however, which Mr. D. Page is working out with ability, he begs to offer the following suggestion. The true base of the Old Red Sandstone, properly so called, is seen in Shropshire and Herefordshire to be a red rock, containing Cephalaspis and Pteraspis, which gradually passes down into the grey Ludlow rock; and in both of these contiguous and united strata, remains of large Pterygoti, but of different species in the two bands, are found. Now, although the Arbroath paving-stone, and the grey rocks ranging to the north of Dundee, lithologically much resemble the uppermost Ludlow rock, they contain the *Cephalaspis Lyellii* as well as *Pterygoti*, and must, under every circumstance, be viewed as the base of the Devonian rocks. In speaking of the lowest member of the Old Red Sandstone, as characterized by the Cephalaspis, the author expressed his conviction, that in the north-eastern Highlands and Caithness that zone is represented as above mentioned, by the vast thickness of thin-bedded red sandstone and conglomerates, which underlies the bituminous flags of Caithness.

The author, who had recently visited Dura Den, in Fifeshire, in the company of Lord Kinnaird and the Rev. Dr. J. Anderson, whose work, 'The Course of Creation,' is well known to geologists, declared that there could be no doubt that the yellow sandstones, that tract in Fife which pertains truly to the Old Red group, are entirely subjacent to the lowest carboniferous sandstones, and are probably of the same age as the upper yellow sandstones of Elgin. A drawing, prepared by Lady Kinnaird (the splendid specimen having been placed in the museum at Rossie Priory), of the fossil fish *Holoptychius* *, nearly three feet in length, which was found on the occasion of this visit on the property of Mrs. Dalgleish, was exhibited; and as this form abounds

* This large species has proved to be the *H. Andersoni*, Ag.

in the lower and redp ortions of the deposit, and also occurs in the overlying yellow sandstones, associated with other old red ichthyolites, the age of the deposit is clearly substantiated.

In conclusion, Sir Roderick said that this communication must be considered as a rehearsal only of what he hoped would be done with more effect next year at Aberdeen, when further observations might lead him either to confirm or modify that portion of his views which relates to the age of the Elgin sandstones. In the mean time, the fundamental reform of the North Scottish series is above narrated, proving that the ascent from rocks on the west coast, which are unquestionably older than any in England and Wales, through Cambrian and Lower Silurian rocks to the much younger "Old Red Sandstone" of the east coast, is firmly established. The communication was illustrated by several geological maps, to indicate the successive steps in knowledge, including an old one coloured by himself thirty-one years ago, the maps of M'Culloch, Nicol, and Knipe, and a map of Sutherland, which the author had coloured during the summer. Besides large diagrams, there were sketches of the mountains and lochs of the west of Sutherland by Miss Charlotte Dempster.

On the Age and Relations of the Gneiss Rocks in the North of Scotland. By JAMES NICOL, *F.R.S.E., F.G.S., Professor of Natural History in the University of Aberdeen.*

The author expressed his regret that in one point he was compelled to differ from his distinguished friend Sir R. I. Murchison. He could not regard the entire gneiss forming the central regions of Ross and Sutherland as of younger age than the red sandstone and quartzite of the west coast (Cambrian and Silurian of Murchison). He described a section from the Gairloch to the Moray Frith, and showed that the red sandstone and quartzite resting on the gneiss of the west, were cut off by a mass of felspar-porphyry and serpentine from the supposed overlying rocks on the east. He had traced a band of similar igneous rocks at intervals for a hundred miles, from Loch Eriboll to Skye, and had observed other indications of fracture and convulsion along this line, as shown in the section exhibited. He therefore concluded that the overlap of gneiss on quartzite might be occasioned by a slip or convolution of the strata, and not mark the true order of superposition. He also stated, that the unconformability of the quartzite to the red sandstone (Cambrian) which he had described at Assynt and on Loch Broom, did not seem to occur in Gairloch, where the two deposits, as seen in great sections on the escarpments of the mountains, appear quite conformable; the red sandstone, however, extending far beyond the quartzite on the west. He further pointed out, that, in the central region of Scotland, from Aberdeenshire to Argyllshire, the great formation of gneiss, with limestone and quartz rock, overlies the mica slate, and does not dip under it, as usually represented. In particular, the gneiss of the Black Mount and Breadalbane Highlands appears to form a wide synclinal trough resting on both sides on mica slate, and thus to be an overlying and younger formation.

On the Comparative Geology of Hotham, near South Cave, Yorkshire. By the Rev. T. W. NORWOOD, *of Cheltenham.*

The village of Hotham is upon the lower lias; but all the secondary rocks of this part of Yorkshire, from the new red sandstone to the chalk inclusive, may be seen in its immediate neighbourhood. Their course is nearly N.N.W. At Hotham proper we are only concerned with the *lias and inferior oolite*; to them therefore these remarks are limited.

I. Between North Cave and South Cliff the lower lias "limestones and shales" present to the plain their usual elevated outcrop, and exhibit plentifully their characteristic fossils—*Gryphæa incurva, Lima gigantea, Ostrea liassica, Modiola minima,* and many other familiar forms. The "Bone-bed" and "Insect-bed" appear to be wanting. The lias passes conformably, and somewhat suddenly, into the sandy beds below it.

A great destruction has happened to the lower lias in this locality. The north side of North Cave is built on a thick drift of the *Modiola minima* bed, excessively crowded with a doubtful shell called provisionally a Posidonomya; and between North and South Cave, in "Sandy Lane," is an extraordinary drift of *Gryphæa incurva*. These two drifts are remarkably independent of each other.

II. There seems to be no facility for examining the upper beds of the lower lias, though that formation is a mile across. The *middle lias* forms a beautiful bank on the east side of Hotham Park, and sections can be seen near North Cave, in a marl-pit and a road-side cutting. The beds change upwards thus—from blue shales at the bottom, through brown shales and sand with irregular broken bands of nodular clay-ironstone, to a hard rock-bed of the true *marlstone* 2 or 3 feet in thickness, which again is capped at the top of the ascent by a very rubbishy ferruginous rock, the lowest member of the *ironstone* series. These ironstones contain a good many fossils; but are most distinguished by Belemnites and *Rhynchonella tetraedra*. Many fossils also of the *marlstone* band have been found in drift between Hotham and Newbald. In the same drift are shells of the upper lias and Oxford clay, though neither of these rocks is yet known with certainty to exist *in situ* near Hotham.

III. Between the middle lias and inferior oolite there is a remarkable thin band of marly limestone, which is called at present the "*Ligniferous marl*." It has a very freshwater appearance, and contains fragmentary remains of ferns and other land plants. Its marine remains consist chiefly of two species of Urchins, with Pinnæ, Pectens, and Modiolæ, each of a single species, and always in good preservation. This band seems never to have been described before in any locality.

IV. The oolite of "Hotham Quarry" appears to be *inferior* oolite, and a distant equivalent of the "Roestone" of Cheltenham. It is strange that this bed should have been said to be wholly restricted to the vicinity of the town of Cheltenham. Its fossils, and more or less of its structure, may be seen in other places; as at Haresfield in Gloucestershire, and at Hotham. At Hotham perhaps the most common form is *Pygaster semisulcatus*; which is at present supposed, on the best authority, to be strictly confined to the *inferior* oolite. The fossils associated with it lead to the same conclusion: they are most of them common at Cleeve and Crickley, near Cheltenham.

On a New Genus (Dimorphodon) *of Pterodactyle, with remarks on the Geological Distribution of Flying Reptiles. By* Professor Owen, *M.D., LL.D., F.R.S.*

The author exhibited a drawing of the skull and some of the wing-bones and other limb-bones of a Pterodactyle which he had obtained during a recent visit to Lyme Regis, in Dorsetshire. The specimen in question was discovered in the lower lias of that locality, and had been purchased for the British Museum. The fore-part of the cranium was preserved, anterior to the orbit, measuring in length 6 inches. This was peculiar for the vast expanse of the long nostril, which was oval, and measured 3 inches by 1½ inch; the antorbital vacuity, divided by a slender oblique bar from the nostril, was triangular, 1 inch 5 lines in long diameter; the solid part of the premaxillary in advance of the nostril measured only 1 inch 9 lines in length, or little more than half the length of the nostril—proportions which had not been previously observed in any Pterodactyle. The largest teeth were implanted in this part of the upper jaw. One, which had been displaced and showed the oblique basal cavity and depression, formed by a successional tooth, measured more than an inch in length. The largest exserted crown of a premaxillary tooth in place measured 7 lines. A tooth situated 3½ inches behind the first tooth, had a crown 5 lines in length; then followed three shorter teeth, and behind these, and below the antorbital vacuity, were several small teeth, with intervals. The dentary bones of the lower jaw were preserved, measuring 6½ inches in length. These exhibited a peculiarity of dentition not previously described or figured; viz. two long prehensile teeth at the fore-part of each ramus, separated by an interval of half an inch, and followed, after a similar interval, by a series of much more minute and close-set teeth, with straight, short, compressed, lancet-shaped crowns, none of which exceeded a line in length. Forty-five of these teeth might be counted in an alveolar extent of 2 inches 9 lines, and in a part of the dentary bone averaging 8 lines in depth. This character of dentition was such, that the figure published by Dr.

Buckland of the fragment of a jaw found in the same lias at Lyme Regis, with similar minute serial teeth, "like one another, flat, and shaped at the point like a lancet," and which he believed was "probably that of our Pterodactyle," was deemed by most palæontologists to have been rather a portion of the jaw of a fish. The *Pterodactylus Banthensis* and *Pterodactylus Gemmingi*, distinguished by an edentulous production (processus mentalis), from the fore-part of the jaw, had three or four large teeth next behind that process, followed by several smaller teeth; and these Pterodactyles formed the genus *Ramphorhynchus* of V. Meyer: but the hind-teeth were not nearly so numerous and minute as in the specimen from the lower lias, and this had no edentulous "processus mentalis." So marked a difference from the dentition of the species of the true *Pterodactylus*, represented by *Pter. longirostris* and *Pter. crassirostris*, as well as from the mandibular and dental characters of the *Ramphorhynchus* of V. Meyer, appeared to call for the subgeneric separation of the *Pter. macronyx* of Buckland from the later forms of *Pterosauria*: and Professor Owen proposed the name *Dimorphodon* for this new subgenus, in reference to the two kinds of teeth, or two features of dentition, one of them borrowed, as it were, from the fish or batrachian, by this early form of flying dragon. Among the bones associated with the skull, the author defined the lower half of a radius and ulna; four metacarpals, including the very thick and strong one of the wing-finger; the first, second, and great part of the third phalanges of that finger; phalanges, including two unequal ones, of the short claw-bearing fingers; portions of the radius and ulna, and the entire metacarpal of the wing-finger of the other fore-limb; a few vertebræ and ribs. Only three of these bones could be compared with the first specimen of a Pterodactyle from Lyme Regis, described by Dr. Buckland: their respective lengths were as follows:—

Pterodactylus (Dimorphodon) macronyx.

	1st Specimen.			2nd Specimen.	
	in.	lines.		in.	lines.
Length of metacarpal of fifth or wing-finger...........	1	5	......	1	8
Length of first phalanx of fifth or wing-finger........	3	9	......	4	6
Length of second phalanx of fifth or wing-finger......	4	9	......	4	9
Length of a claw-phalanx	0	8½	......	0	9

By this comparison it was shown that the second specimen was larger than the first, but differed so slightly in the proportions of the first and second phalanges, as not, in Professor Owen's opinion, to justify a distinction of species: more particularly since, on the supposition of the portion of jaw figured by Dr. Buckland having belonged to the same individual as the limb-bones figured by the same author, the first specimen of *Pterodactylus macronyx* had the same subgeneric character of mandibular teeth as the second specimen from the same formation and locality.

Some portions of thin-walled hollow bones from the upper beds of the Trias of Wirtemberg might belong to the Pterodactyle genus; in which case they would indicate the oldest examples known of the flying order of reptiles. The oldest certainly known Pterodactyles were, at present, the *Pterodactylus macronyx*, Bd., of the lower lias, forming the type of the subgenus *Dimorphodon*; and bones of Pterodactyle from the coeval lias in Wirtemberg. The next in point of age was the *Pt. Banthensis*, from the 'Posidonomyenschiefer' of Banz, in Bavaria, answering to the alum-shale of our Whitby lias. Then follows the *Pter. Bucklandi*, from the Stonesfield oolite. Above this came the first-defined and numerous species of Pterodactyle from the lithographic slates of the Middle Oolitic system; as at Solenhofen, Pappenheim, and Nusplingen, in Germany, and from Cirin, on the Rhine. The Pterodactyles of the Wealden were, as yet, known by only a few bones and bone-fragments; as had hitherto been also those of the 'Greensand' of Cambridgeshire. Finally, the Pterodactyles of the Middle Chalk of Kent, so remarkable for their great size, constituted the last forms of flying reptiles known in the history of the crust of this earth.

On Remains of New and Gigantic Species of Pterodactyle (Pter. Fittoni *and* Pter. Sedgwickii) *from the Upper Greensand, near Cambridge. By* Professor Owen, *M.D., LL.D., F.R.S.*

Professor Owen communicated the results of an examination of an extensive series of fragmentary remains of Pterodactyles which had been discovered in the Upper Greensand formations, now extensively worked for phosphatic nodules, near Cambridge.

Among these were many more or less entire vertebræ demonstrating their procœlian type, as in modern Lizards; the Pterodactyles being the earliest known vertebrate animals with 'cup-and-ball' vertebræ, and with the 'cup' at the fore-part of the centrum. The atlas consists of a centrum, two slender styliform neurapophyses, and a neural spine, which is small and discoid. The centrum is a thin disc; flat where it joins, and becomes anchylosed to, the axis; concave for the occipital tubercle. The neurapophyses, resting on the upper part of the sides of the centrum of the atlas, converge and articulate above with two tubercles on the fore-part of the neural arch of the axis. The centrum of the axis is 8 lines longer than that of the atlas, which was one line long in the specimen described. It expands posteriorly, where it terminates, below, in a pair of short obtuse apophyses, above which is the convexity for articulating with the third vertebra. At the middle of the under surface is a low hypapophysial ridge. At the middle of the side of the centrum is the large pneumatic foramen. The neural arch is anchylosed with the centrum, and sends off from each posterior angle the zygapophysis, which has a tubercle above and a flat articular surface below looking downward, and a little outward and backward. The neural canal expands at the posterior outlet. The neural spine is broken away.

In the ordinary neck-vertebræ the centrum is oblong and subdepressed, slightly compressed at the middle, subcarinate at the fore-part of the under surface, the back part of which expands and is slightly produced into a short thick obtuse process on each side. The anterior concavity is a long transverse oval; beneath which, in most, is a tuberosity terminating there the median keel. The posterior ball has a similar transversely extended elliptical figure—the characteristic of the neck-vertebræ of the Pterodactyle, but tilted up by the curve of the under surface of the centrum, above the level of the two terminal tuberous processes. A large pneumatic foramen, of an elliptic form, opens upon the middle of each side of the centrum close to the anchylosed base of the neurapophysis. The texture of the centrum presents a few very large cancelli, which doubtless received the air from the cervical air-cells. The surface of the centrum is formed by a very thin compact layer of bone, a little thicker where it forms the articular cup.

The neural arch, between the notches for the nerve-outlets, is not quite two-thirds the length of the centrum; the hinder notch is the deepest; the arch is low and broad, less concave on each side than it is before and behind, with the four angles rather produced, and supporting the articular surfaces, of which the two anterior look upward and forward, the two posterior downward and backward. The sides of the arch extend outward so as to overhang those of the centrum. The posterior zygapophyses do not extend so far back as the articular ball of the centrum.

At the base of the neck, or beginning of the back, the vertebræ suddenly decrease in length; the hypapophysis disappears, or is represented only by a slight production of the lower border of the anterior cup; the parapophyses are less produced, the lower surface of the centrum is flattened, and presents a quadrate form. There is now a considerable development from the fore-part of each side of the neural arch and contiguous part of the centrum, and thereby the last cervical or first dorsal vertebra of the Pterodactyle more resembles the corresponding vertebra of the bird. The parapophysis, diapophysis, and rudimental rib coalesce around the vertebrarterial foramen; an oblique ridge is continued from the upper border of the anterior articular cup upon the parapophysis; a parallel oblique ridge is continued from the anterior zygapophysis downward and outward upon the pleurapophysis; the diapophysis makes a low obtuse projection above the pleurapophysis and behind the zygapophysis. Above these developments the neural arch contracts from before backward, to an extent of 5 lines, as compared with a total vertebral breadth, anteriorly, of 1 inch 8 lines; it then rapidly expands, rising vertically at its fore part, and developing at its back part the posterior zygapophyses, the articular facets of which look more directly outward than in the long cervical vertebræ; the superincumbent tubercle is more distinct from the facet; the posterior zygapophyses are also much more approximated than in those vertebræ; they are separated behind by a semicircular concavity; the base of the neural spine in the vertebra here described measured 6 lines in length by 3 in breadth. The pneumatic foramina are at the back part of the base of the diapophysis. The articular surfaces of the centrum retain the transversely extended form, and are simply concave before and convex behind, which at once distinguishes the Pterosaurian hind-cervical vertebra from that of the bird.

In the dorsal region the vertebral centrum, retaining its shortness, gains in depth, and presents the more usual proportions of cup-and-ball reptilian vertebræ. The under surface is smooth and even, very slightly concave lengthwise, convex transversely. The parapophysis disappears, and the diapophysis, which alone supports the rib, after the first or second dorsal, is sent off from a higher position in the neural arch.

Sacrum.—The Woodwardian Museum contains a specimen of the bodies of three anchylosed sacral vertebræ, the first being demonstrated by part of its anterior concave articular surface for the last lumbar vertebra. The groove for the passage of the nerve notches the back part of the parapophysis, close to the line of suture with the second sacral. In this vertebra the corresponding nerve-notch is more advanced, leaving a short sutural surface behind, indicative of a position of the neural arch crossing for a short extent the line of junction of the second with the third sacral centrum. The parapophyses of the second and third vertebræ are sent off almost on a level with the lower surface of the centrum, which is flattened.

The fore-part of the sacrum of a much larger Pterodactyle, from the Cambridge Greensand, differing also in the less transverse convexity of the under part of the first centrum, measures 11 lines across the shallow anterior articular concavity, and 14 lines from the lower part of the centrum to the fore-part of the base of the neural spine. The neural canal is circular and 2 lines in diameter; above it the neural arch rises like a vertical wall for 5 lines, where the spine has been broken off.

Caudal Vertebræ.—From the number of elongated caudal vertebræ in the series of fossils from the Cambridge Greensand submitted to the author—not fewer than seven—he believes the large Pterodactyle from that formation to have had a long tail, but moveable, not stiff through anchylosis of the vertebræ, as in *Pter.* (*Rampho-rhynchus*) *Gemmingi*, V. Meyer.

PTERODACTYLUS SEDGWICKII, Owen.—This species is founded on a specimen of the fore-part of the upper jaw, containing the first seven sockets of the teeth, in a few of the anterior of which the base of the tooth is retained. The first two sockets open upon the obtuse extremity of the jaw, and have a direction showing that their teeth projected obliquely forward, so as to prolong the prehensile reach of the jaw; the second and third sockets are the largest, and cause a slight transverse swelling; the fourth is suddenly smaller, and the three following retain nearly the same size, or show a slight increase as they pass backward. The apertures of the sockets are elliptic, with the long axis extending obliquely from before outward and backward, not parallel with the axis of the jaw. The interval between the two sockets is about half the long diameter of each. The anterior termination of the jaw is obtuse; the sides are smooth, flat, converging at an acute angle to what almost forms a ridge above; the jaw gradually increases in vertical diameter as it proceeds backward, the upper contour being straight as far as it can be traced in the fossil. The palatal surface is entire, narrowest between the second sockets, suddenly broader and flat between the third pair, retaining about the same breadth, but with a slight convexity and feeble indication of a median ridge in the rest of its extent.

The Pterosaurian nature of this fossil is shown by the extreme thinness of the compact bony wall of the jaw; its relation to the genus *Pterodactylus*, as contra-distinguished from the *Rhamphorhynchus*, V. Meyer, is proved by the terminal position of the sockets; and sufficient of the outer side-wall of the jaw is preserved to show that the nostril did not advance so far forward as in *Dimorphodon*—the generic form of Pterodactyle from the lower lias.

By its size and true or proper pterodactyle affinities, the present specimen most resembles *Pterodactylus Cuvieri*, Owen, from the Chalk of Kent; but it offers the following well-marked differences—a greater proportional size of the anterior sockets with a corresponding expansion of the fore-part of the jaw; a greater number and closer arrangement of the sockets; a greater depth of the jaw, in proportion to the breadth of the palate. The extent of the jaw, *e. g.*, containing the first seven sockets in *Pterodactylus Sedgwickii*, is 2 inches 9 lines, but in *Pterodactylus Cuvieri* it is 3 inches 6 lines; the depth of the jaw, above the third socket, in *Pter. Sedgwickii* is 14 lines, in *Pter. Cuvieri* it is 8 lines; whilst the breadth of the palate between the third pair of sockets is only one line less in *Pter. Cuvieri* than in *Pter. Sedgwickii*. It needs only to compare the fore-part of the jaw of the great Chalk Pterodactyle with the same part of the still larger species from the Greensand, to be convinced of their specific distinction.

The difference is still more marked between *Pterodactylus Sedgwickii* and the *Pterodactylus compressirostris*, Ow., from the Chalk. The rapid increase of depth as the jaw extends backward, in *Pter. giganteus*, Bk., shows that that comparatively small species cannot be the young of the present truly gigantic Pterodactyle of the Upper Greensand. The author, therefore, has founded, on the above-described fossil, a new species, at present the largest known in the order of Flying Saurians, which he proposes to dedicate to the Woodwardian Professor of Geology in the University of Cambridge, who for forty years has discharged the duties of that office with exemplary zeal and a rare eloquence, has almost created the Museum still called Woodwardian, and, during the same period, has enriched geological science by original researches which have thrown light on its most obscure and difficult problems.

PTERODACTYLUS FITTONI, Owen.—This species is also founded on the fore-part of the upper jaw of a Pterodactyle, with the first and second pairs of alveoli. In the minor depth of the jaw compared with its basal breadth, in its more obtusely rounded upper surface, and in the greater extent of space between the alveoli of the same size, this maxillary fragment indicates a very distinct species from the *Pterodactylus Sedgwickii*, but one probably not much inferior in size. The author dedicates it to his friend Dr. Fitton, F.R.S., one of the Founders of the Geological Society of London, and who may be regarded as the discoverer of the system now called 'Neocomian,' which includes the Greensand matrix of the Flying Reptiles under consideration.

The sockets in the present fragment may answer to the second and third in the foregoing, though there scarcely seems room for a pair in advance of the foremost in the present specimen; be that as it may, the distance between the first and second socket in the specimen of *Pterodactylus Fittoni* is, relatively to the size of the socket, greater than the interval between the second and third sockets in *Pterodactylus Sedgwickii*, and much greater than that between the second and third sockets. The outer wall of the largest anterior socket in *Pter. Fittoni* is much less prominent than in *Pter. Sedgwickii*, and the lateral expansion of the fore-part of the upper jaw must have been relatively less: the form of the bony palate is different, there being a distinct though shallow longitudinal groove on each side a low obtuse median ridge. The diastema between the second and third tooth is shown to exceed the long diameter of the second socket, recalling the proportion of the interspaces in *Pterodactylus Cuvieri*; but the jaw is broader in proportion to its height in *Pterodactylus Fittoni*.

PTERODACTYLUS, sp. inc.—This is represented by a portion of an upper jaw including a part of two sockets, in one of which the root of the tooth remains. The outer wall of the jaw is nearly flat, very slightly convex below, and as slightly concave above, vertically; the upper margin showing no indication of any bend or inclination to the upper border of the jaw, the height or vertical diameter of which remains conjectural: that it was, at least, one-third more than the portion preserved, may be estimated from the extent of the socket of the tooth being equal with the preserved part of the wall. A coat of roughish cement, one-third of a line thick, is preserved upon the upper half of the tooth-root; below this is seen the smooth dentine; and, where it is broken, the pulp-cavity is exposed, filled by the greensand matrix. The length of the implanted part of this tooth is 1 inch 4 lines; the long diameter of the transverse fracture at the base of the crown is ½ an inch, the short diameter is 4½ lines. Estimating the length of the exserted enamelled crown to equal that of the inserted cemented base of the tooth of a Pterodactyle,—and it is sometimes greater in the long anterior laniariform teeth,—we may assign a length of 2 inches 8 lines to the teeth implanted in the part of the upper jaw here described. The interspace between the two sockets is 3½ lines, or half that of the long diameter of the socket: the plane of the opening of the socket, and the interspace, present the same obliquity as they do in *Pterodactylus Sedgwickii*; and, as the proportion of the interspace to the socket is also the same, the present fragment has most probably belonged to a larger individual of the same species. Since the outer border of the sockets does not swell out beyond the outer wall of the jaw, the fragment has been part of the jaw situated behind the anterior swelling caused by the proportionally large prehensile teeth; and as, from the analogy of known Pterodactyles, the teeth succeeding those anterior ones are not of larger size, but are usually smaller, at any posterior part of the jaw, we may therefore, with due moderation, frame an idea of the Pterodactyle to which the present maxillary fragment belonged, as surpassing in size that to which the portion of the jaw of *Pter. Sedgwickii* belonged, in the proportion in which the socket in the present exceeds the last socket in that fragment. Such an idea impels to a close scrutiny of every character or indication of the true generic relation of the present fragment in the reptilian class: but the evidence of the large and obviously pneumatic vacuities, now filled by the matrix, and the demonstrable thin layer of compact bone forming their outer wall, permit no reasonable doubt as to the pterosaurian nature of this most remarkable and suggestive fossil.

All other parts of the flying reptile being in proportion, it must have appeared, with outstretched pinions, like the soaring Roc of Arabian romance, but with the demoniacal features of the leathern wings with crooked claws, and of the gaping mouth with threatening teeth, superinduced.

Teeth of the large Pterodactyle.—Various teeth, but few quite entire, have been rescued by the care and perseverance of Mr. Lucas Barrett, from the rubbish of fragmentary fossils accumulated during the diggings for phosphatic nodules in the Greensand deposits near Cambridge. Guided by the proportions of length to breadth, by the elliptic section, and the concordance of the minute markings on the crown and base with those on the portions of teeth remaining in the above-described jaws of *Pterodactylus*, many of the above-detached teeth can be satisfactorily referred to that genus.

The base or implanted part of one of the largest of these teeth has belonged to a Pterodactyle as large as that represented by the fragment of jaw last described; it presents the same elliptical transverse section as the implanted base of the tooth in that fragment, shows a widely excavated pulp-cavity at the base, and gradually tapers to the crown: the cement, about ⅓rd of a line in thickness, is roughened by longitudinal grooves, not continuous for any great length, but uniting, or bifurcating, in an irregular reticulate pattern, forming long and very narrow meshes, the raised interspaces being equal in breadth to the grooves. In a few teeth the base shows an oblique depression, evidently due to the pressure of a successional tooth; in these the basal pulp-cavity is more or less filled up by ossification of the pulp. The enamel of the crown seems smooth and polished; and, under the lens, shows only extremely delicate, slightly and irregularly wavy, longitudinal, but often interrupted or confluent ridges.

Portions of the scapular arch, the humerus, antibrachial and carpal bones were next described. The distal end of the metacarpal of the fifth or winged finger is trochlear; but the pulley is more complex than in other animals with similar joints, there being three convex ridges traversing the articular surface from behind forward, and describing more than half a circle; the middle ridge less produced than the lateral ones which form the sides of the pulley. The direction of the ridges is rather oblique. The outer ridge is rather more produced and of a less regular curve than the inner ridge. The outer ridge begins by a rising at the middle of the fore-part of the distal end of the shaft, which bends obliquely outward and meets the outer angle of that part of the shaft where the outer trochlear ridge begins to be prominent; this ridge then extends with a feeble convex curve to the back part of the trochlea, where the convexity of the curve increases, and it terminates by projecting a little beyond the level of the outer almost flattened side of the trochlea. The articular surface, as it extends from the margin of this element of the trochlea inward, is first gently convex, then sinks to a concave channel by the side of the low median convexity. The inner ridge begins from the inner side of the fore-part of the bone, and describes a pretty regular semicircular curve as it extends backward and a little outward, to terminate near the middle of the back part of the distal end of the shaft; thus, owing their obliquity to a termination of the inner ridge near the middle of the back part, and to the beginning of the outer ridge near the middle of the fore part, of the metacarpal bone, these principal ridges of the trochlear joint recede from each other at the middle of the joint, and approximate at the fore and back ends of the joint. As the back ends of the two lateral ridges are on the same transverse line, and the front end of the inner ridge rises higher upon the shaft than that of the outer ridge, this is by so much the shorter of the two. The low middle ridge is much shorter than either of the lateral ones, being confined to the lower and middle part of the trochlea, to which it gives an undulating transverse outline.

The portions of the wing-bones of the Pterodactyles of the Cambridge Greensand, here described and figured, show the same superior proportions over those of the great Pterodactyles from the Kentish Chalk, as do the portions of jaw-bones and teeth.

The long diameter of the expanded end of the largest of the wing-bones of a Pterodactyle from the Cambridge Greensand is 3 inches.

The transverse diameter of the distal end of the humerus of the *Pterodactylus grandis*, Cuv., the largest species hitherto obtained from the Lithographic Slates of Germany, is 1 inch 3 lines; neither the radius, ulna, nor metacarpal of the wing-bone of the same species presents a diameter of its largest end equalling 1 inch.

The articular end of the long wing-bone, 3 inches thick, being most probably that of an antibrachial bone, and the total length of the bone, whether radius or ulna, being, according to the proportions of either of these bones in the *Pterodactylus suevicus*, 16 inches, the following would be the length of the other large bones of the wing in the large Pterodactyle to which the above-cited specimen belonged, according to the proportions which the other wing-bones bear to the radius or ulna in the *Pterodactylus suevicus*:—

	ft.	in.	lines.
Humerus	1	0	0
Radius	1	4	0
Metacarpus or wing-finger	1	8	0
First phalanx of wing-finger	2	3	0
Second phalanx of wing-finger	1	9	0
Third phalanx of wing-finger	1	5	0
Fourth phalanx of wing-finger	1	1	0
Total length of long bones of one wing	10	6	0

Supposing the breadth of the Pterodactyle between the two shoulder-joints to be 8 inches, and allowing 2 inches for the carpus and the cartilages of the joints of the different bones in each wing, we may then calculate that a large *Pterodactylus Sedgwickii* would be upborne on an expanse of wings of not less than 22 feet from tip to tip.

The author looks forward with confidence to future acquisitions of remains of the truly gigantic *Pterodactylus* of the cretaceous periods, more especially from the Greensand locality near Cambridge, as a means of throwing more light on the peculiar osteology of the extinct flying reptiles.

For the opportunities at present afforded him, he expressed grateful acknowledgments to his old and much esteemed friend the Rev. Professor Sedgwick, F.R.S.; to the acute and active Curator of the Woodwardian Museum, Mr. Lucas Barrett, F.G.S.; to James Carter, Esq., M.R.C.S., Cambridge; and to the Rev. G. D. Liveing, M.A., of St. John's College, Cambridge.

On the Skeleton of a Seal from the Pleistocene Clays of Stratheden, in Fifeshire. By D. PAGE, *F.G.S.*

The Springfield brick-works, where the only remains of the Seal family which had yet been discovered in any of our post-tertiary deposits* were found, are about nine

* Since the meeting at Leeds, portions of the skulls of two seals have been found by Mr. Jamieson in the Pleistocene beds of Aberdeenshire, and the pelvic bones of another in the brick-clays of Kirkcaldy, Fifeshire. It would also appear from the Transactions of the Wernerian Society of Edinburgh, that about thirty years ago "the remains of a quadruped, supposed to be those of a seal," were discovered in the brick-clays of Falkirk, in the upper basin of the Forth.

miles from the open sea of St. Andrew's Bay, more than five from the highest influence of the tide in the estuary of the Eden; and the clay hills rise from 120 to 150 feet above the medium tide-level of the German Ocean. There are several well-marked ancient sea-margins in the valley of the Eden, whose estuary, now only about three miles long, and less than a mile in breadth, must have extended fully twenty-five miles inland, and ranged from two to five miles in width. The most marked of these old sea-levels are at 20, 40, 60, 90, 150, and 200 feet above the present sea—the lowest yielding shells, &c. wholly of the existing shores, though overlying a well-marked submerged forest of pine, oak, birch, hazel, alder, and other British trees; the second containing bones of the whale, and several shells of boreal species; the third and fourth rarely containing remains, and the fourth bones of whales and the skeleton now in question. The clay in which the skeleton was imbedded is a bright red plastic clay, evidently derived from the waste of the Old Red Sandstone of Upper Stratheden, when the waves washed the bases of the present hills, and the streams brought down from the Lower Ochils the *débris* of the same formation. It contains no boulders or pebbles, and appears to have been a tranquil deposit in water of considerable depth and removed from the influence of drift, either vegetable or animal, from the adjacent shores. It rests on the true boulder clay, which is there a dark blue tenacious mass of great thickness, and replete with boulders of granite, syenite, greenstone, gneiss, quartz, and other primary formations. The descending section shows—arable soil and sandy clay 3 feet; laminated sand 1 foot; from 15 to 20 feet of red plastic clay, in which the skeleton was imbedded at a depth of 12 feet—the whole being underlaid by blue boulder clay of unknown depth. From the position of the red clay, and the disposition of the associated gravel mounds, it is evident that it is younger than the boulder bed on which it rests, and that it is as old at least as the 150-feet beach, and greatly older than the silts and gravels which in the Forth, Clyde, and Tay have yielded remains of whales, antlers of gigantic red deer, skulls of the *Bos longifrons*, wolf, bear, and beaver, and shells, many of which are of boreal species. How much younger than the boulder clay we have no direct means of determining, though evidently much older than the human occupation of Britain, which must have then been sunk to a depth of from 150 to 200 feet below its present level. As regards the skeleton itself (which is that of a young animal, and in a wonderful state of preservation), it seems to be a pretty widely divergent variety of the common seal (*Phoca vitulina*), if not a distinct species; a point, however, that yet awaits the precise determinations of the comparative anatomist. If the same as the existing seal, then it invests that creature with a high degree of antiquity; if of a different species (boreal or more southerly), then it shows the high age of these brick-clays, and may assist to identify their position in other localities.

Farther Contributions to the Palæontology of the Tilestones or Silurio-Devonian Strata of Scotland. By D. PAGE, *F.G.S.*

Without entering on the stratigraphical relations of these tilestones (which would be discussed at a subsequent meeting), he might simply mention, that part of them, as in Lanarkshire, seemed to cap and form portion of the Upper Silurians, while the larger portion, the Forfarshire flagstones, undoubtedly constituted the basis of the Old Red Sandstone; hence, with a view to avoid all discussion in the mean time, he had ranked the whole as "Silurio-Devonian," or "Pterygotan Beds." Beginning with the Lanarkshire beds, he had, since the Glasgow meeting, been enabled to add several new forms to the fossil Fauna of that district, for as yet no trace of vegetation had been detected in these strata. In addition to *Trochus helicites* and *Lingula cornea*, which were then known, he had now to add *Pterinea*, *Orthonota*, *Nucula*, *Avicula*, *Orthoceras*, and other well-marked Ludlow or Upper Silurian shells. To the Crustaceans then known, viz. *Beyrichia*, *Ceratiocaris*, and *Himanthopterus*, he had now to add several discoveries which rendered the structure of these curious crustaceans more apparent, besides the detection of two entirely new forms, which he would venture to term provisionally *Stylonurus spinipes* and *S. clavipes*, in allusion to their pointed style-shaped caudal termination, and to the characteristic form of their swimming paddles, or third pair of organs which spring from the under side of their cephalo-thorax. Turning to the Forfarshire beds, which in 1855 were known to yield little more than obscure vegetable forms, *Parka decipiens* of Lyell, *Pterygotus*, and *Cephalaspis*, he was now enabled to add several new and gigantic forms of Fucoids, a *Cyclopteris*, and a Lepidodendroid stem, which was clearly of terrestrial origin. To the Fauna he has added gigantic Foralites and Scolites, or annelid burrows and annelid tracks, and an organism which appeared to be the remains of an annelid itself. There had also been discovered several new portions of *Pterygotus*, which rendered the true structure of that gigantic crustacean much more apparent; and he had also been enabled to describe and figure two new crustaceans under the names of *Kampecaris* and *Stylonurus*, the latter closely related in structure to *Eurypterus*, and approaching the forms of those found in the Lanarkshire strata. To *Cephalaspis*, of which little more was known than the head and bony ring-plates of the body, he had now to add a well-marked corneous eye-capsule, a pair of pectoral fins (or rather swimming paddles), a subdorsal fin, and the true form of the large heterocercal tail;—so that, instead of figuring this much-caricatured fish as had hitherto been the case, as a saddler's knife for the head, and a parsnip with a few radicles for the body, we could now restore it as a legitimate and elegant fish, much resembling in general contour the armed bull-head or Aspidophorus of our present shores. There had also been discovered a vast number of fin-spines or Ichthyodorulites, which were yet undescribed; and a small fish with fin spines and shagreen-like scales, to which he had given the name of *Ictinocephalus granulatus*, in allusion to its kite-shaped head and shagreen-covered body. For the discovery and preservation of these new fossil forms, palæontologists were mainly indebted to James Powrie, Esq., of Reswallie, Forfar, and to Mr. Simon, surgeon, Lismahagow.

On the Relations of the Metamorphic and Older Palæozoic Rocks in Scotland. By D. Page, *F.G.S.*

As was well known, a large development of Silurian strata occurred in the south of Scotland, dipping northward under the Old Red Sandstone, which in turn underlaid the coal-fields of the Forth and Clyde. On the northern side of the coal-basin, the Old Red dipped southward, again underlying the coal-measures; but between the Old Red and the Grampians, no true representative of the Silurian system had as yet been detected. What, then, were the relations of these rocks? He had made many sections during the last two summers, and found that everywhere, from Stonehaven on the east to Bute on the west, a thick mass of trappean conglomerate succeeded the crystalline schists, that this was succeeded by the fissile grey strata of Perth and Forfar, containing *Pterygotus* and *Cephalaspis*, these by the "Great Pebbly Conglomerate," and then the middle Old Red with *Holoptychius*, and the upper yellow beds with *Holoptychius* and *Pterichthys*. The Pterygotan beds, though evidently approaching the upper Silurians of Lanarkshire in fossil characters, were still the basis of the Old Red; and if Silurian strata did exist on the southern slopes of the Grampians, geologists must seek for them either in the trap conglomerate and grits below, or in the clay-slates and mica-schists which might be the metamorphosed equivalents of the Silurians of Peebles, Roxburgh, and Dumfriesshire. Two conclusions thus presented themselves: either the physical geography of the north had been such during the Silurian era, as not to admit the deposition of strata; or having been deposited, as in the south, they had been subsequently metamorphosed and all traces of organic life been obliterated in their crystalline structure. Whichever view might be adopted, we had in the mean time no fossil evidence of Silurian strata on the southern flanks of the Grampians, though in the south of Scotland, and on the south side of the great basin of the Clyde and Forth, a vast development of lower, middle and upper Silurians had been traced and pretty closely examined. Grouping, therefore, the older rocks of Scotland according to the present state of our information, we had something like the following succession:—

Permian	Breccia conglomerates of Annandale.
Carboniferous...	Upper and True Coal Measures. Millstone Grit (feebly indicated). Carboniferous Limestone (Marine). Lower Coal Series (Æstuarine).

OLD RED SANDSTONE	Yellow Sandstone of Stratheden and Elgin. Red Pebbly Sandstones of Perth, Forfar, and Berwickshire. Dark Flagstones of Caithness and Orkney. Great Conglomerates and Pebbly Sandstones. Greyish Red Flagstones of Forfar, Perth, &c. Trappean Conglomerate and Gritstones (thick-bedded and fissile), flanking the South Grampians.
SILURIAN..........	Upper Silurians of Lanarkshire. Middle Silurians of Ayrshire. Lower Silurians of Peebles and Roxburgh. *** Zone of unfossiliferous grauwacke.
METAMORPHIC.....	Clay-Slates (with and without cleavage). Chloritic and Micaceous Schists. Hornblende Schist and Quartzitic Group. Gneiss and Granitoid Schists.

On a recently-discovered Ossiferous Cavern at Brixham, near Torquay. By W. PENGELLY, *F.G.S.*

Notice of some Phenomena at the Junction of the Granite and Schistose Rocks in West Cumberland. By Professor PHILLIPS, *LL.D., F.R.S.*

The author referred in the first place to some excellent observations—the only ones he had met with—of Professor Sedgwick on the little visited region of slate and granite in the extreme south-west of Cumberland. Following in his steps, Prof. Phillips had found an extremely interesting variety of phenomena, from which a few were selected for the present communication, and illustrated by maps and sections.

He described three orders of phenomena, all due to some form of heat action, observed by himself in the slate district of Black Comb, and on the north-west border of that mountain. In the mountain of Black Comb, the black slates, much contorted, are not in a metamorphic state. Several dykes or interposed bands of granite (elvan) lie in the slates of the north-western part of Black Comb; they very slightly affect the condition of the slates. Round a considerable part of Black Comb the green slate series is metamorphic, and the series of changes is such, that from unaltered slate at one end, new structures appear and augment (not very regularly), so as at the other end to complete a green or black porphyry. Agate concretions appear in some places in long pipes parallel to cleavage dip. This remarkable series of changes is traced with great precision in a bold narrow ridge of rock near Bootle, one end of which almost touches the black slate, the other is met by a tongue of granite. Near the junction the granite is hornblendic (syenite); it enters the metamorphic series in veins of fissure, and produces on that series further small changes of colour and texture apparently proportioned to the mass of the introduced rock. Thus in one district, possibly due to one general cause, the earth's internal heat, but operating through long time, under different conditions, three distinct orders of phenomena appear, for each of which a special investigation is necessary, and to which, when fully understood, a special explanation may be applied.

On the Hæmatite Ores of North Lancashire and West Cumberland. By Professor PHILLIPS, *LL.D., F.R.S., and* Mr. R. BARKER, Jun.

Prof. Phillips embodied in his remarks on the iron-ores of North Lancashire, the substance of a communication from Mr. R. Baker, jun., 'On the Hæmatite Deposits of West Cumberland.' The districts of North Lancashire and West Cumberland, to which reference was made, were rich in deposits of peroxidated iron ore, and were now producing, probably, not less than one million of tons per annum. Notwithstanding their value, they had not been carefully examined until a recent period, but some interesting geological phenomena had now been observed, which threw considerable light on the age of the iron-ore formations of West Cumberland and North Lancashire. The iron ore of these districts was found in immediate connexion with mountain limestones, and many persons had been in the habit of regarding the ore as of the same age as the mountain limestone, and as being part of the limestone series; but a careful observation of the district of North Lancashire would go far to remove this opinion. Running across the mountain limestone of that district were vast and often devious hollows, and it was in these hollows that the ore is found, lying upon the limestone, and resting on one side against what was evidently a great line of fault, as well as in the fissures and hollows of the rock, with all the indications of a later deposit. The communication of Mr. Baker showed by very exact sections and descriptions, that iron ore was not confined to limestone, but was also to be found in connexion with the adjacent slate formations, showing that it was not a deposit peculiar to the limestone. The opinion which Professor Phillips had formed on this subject he by no means wished to be accepted as a positive conclusion; but the position of the ore, upon the faults of the limestone as well as in the fissures and hollows of the rock, went to prove that it was a subsequent formation. The date to which it could with most probability be referred was that of some parts of the Permian deposits. He was inclined to believe that the lines of faults and fissures, and the sinuous hollows, sometimes cavernous, in the limestone, which had been excavated or modified by water, were due to the action of causes which preceded the period of the Permian system, and that the iron formation might generally be referred to the age of the Permian rocks, and occasionally to a still later date, namely, that of the New Red Sandstone. He was satisfied that the iron ore of Lancashire and Cumberland could not with probability be referred to the period of the mountain limestone.

On a New Method of determining the Temperature and Pressure at which various Rocks and Minerals were formed. By H. C. Sorby, *F.R.S.*

If a tube be filled with air at any particular temperature and pressure, and be afterwards taken to a place where the temperature or pressure is different, the change in the volume of the air would enable us to calculate the difference in the temperature, if the difference in pressure were known, or to ascertain the difference in the pressure, if the difference in the temperature were known. Where crystals are artificially formed from solution in water, they catch up and hermetically enclose in their solid substance small quantities of that liquid, so as to produce fluid-cavities, which, from the nature of the circumstances under which they originate, are just full of the liquid at the temperature and pressure at which they are formed. This fluid is also affected by changes in temperature and pressure, only that of course the actual amount of the change of dimensions and the laws connecting it with the temperature and pressure are not the same as in the case of air. If, then, a crystal be formed at an elevated temperature, but under no very great pressure, when it cools down to the ordinary heat of the atmosphere, the fluid in these cavities contracts, so as to leave a vacuity, the relative size of which must of course depend upon the height of the original temperature. Such fluid-cavities are easily seen with a suitable magnifying power, and the relative size of the vacuity can be measured by means of the micrometer. Applying these principles to the study of natural crystals, it is found that, whilst some indicate a temperature not materially higher than that of the atmosphere, many must have been formed at a heat rising upwards to that of dull redness, which is especially the case with igneous and metamorphic rocks. If, however, the crystals were formed under a very great pressure, of course the above conclusions would be invalidated, and the calculated temperature would be too low; but if we could form some approximation to the actual temperature, we could deduce, from the relative size of the vacuities in the fluid-cavities, the pressure under which the crystals were generated. Where the fluid-cavities in granite rocks are studied in this manner, they lead us to conclude that such rocks were formed under a very great pressure, varying in different cases, but of such a magnitude, as clearly points to their deep-seated, plutonic origin.

On some Peculiarities in the Arrangement of the Minerals in Igneous Rocks. By H. C. Sorby, *F.R.S.*

In both recent and ancient igneous rocks, it is not at all unusual to find crystals of a mineral that fuses at only a moderately high temperature, acting as the nuclei on which crystals of a far less fusible mineral have been formed. Thus, for instance, in the lava of Vesuvius crystals of leucite have very often been deposited on nuclei of augite. If it were supposed that the temperature at which the minerals crystallized was the same as that of their own fusing-point when heated alone, this would appear to be a very unintelligible circumstance, but can easily be explained by supposing that the fused rock is simply a liquid melting at a high temperature, which is capable of dissolving various minerals, in the same manner that the very fusible liquid water dissolves various salts. If a solution of bichromate of potash, nearly saturated at the freezing-point of water, be slowly frozen, small crystals of ice are formed, and on these are deposited small crystals of bichromate of potash, which can no longer be held in solution in the diminished quantity of *liquid* water. Here then, as in the above-named instance of the arrangement of the crystals in lava, crystals of a very fusible substance act as the nuclei on which far less fusible crystals are deposited; and if we suppose that there is a perfect analogy between the two cases,—that both were liquids holding various substances in solution,—the arrangement of the minerals in the igneous rock no longer presents any special or exceptional peculiarity.

On the Currents present during the Deposition of the Carboniferous and Permian Strata in South Yorkshire and North Derbyshire. *By* H. C. SORBY, *F.R.S.*

This was a continuation of a branch of geology on which the author has published several papers, pointing out how the direction and characters of the currents present during the deposition of stratified rocks can be determined (Report, 1855, p. 97). The neighbourhood of Sheffield is extremely well fitted for this inquiry; and from residing there the author has been able to examine minutely a large tract of country, and lay down the direction of the current in many hundred localities on large maps, which were exhibited. The chief conclusions derived from these are, that during the period of the millstone-grit there was a very uniform general current from the north-east, slightly interfered with by a tide setting from the north-west, and by the action of surface-waves and wind-drift currents produced by the powerful westerly gales. This general north-east current was also present during the deposition of the gritstone beds in the lower part of the coal strata, in the shales associated with which genuine marine shells are found, but ceased towards the central portion, more productive in coal, where such marine shells do not occur. In that part of the series, in different localities and beds, the currents were from all parts of the compass; but on the whole are chiefly from the west, as if in some way or other connected with the prevailing westerly winds and wind-drift currents, which here prevailed independent of the tide or general north-east current, on account of the connexion with the main sea having been cut off. During the deposition of the magnesian limestone the sea appears to have been subject to a very decided tide, rising and falling with great uniformity from W.S.W. to E.N.E., amongst a number of shoals on which surface-waves stranded, chiefly produced by easterly winds. The millstone-grit and lower coal-measures therefore present us with an admirable example of the action of a simple current, flowing only in one direction; whereas the magnesian limestone is a very excellent illustration of the effect of oscillating currents moving backward and forward in a particular line, like the currents produced by the rise and fall of the tide.

On the Geology of the Scilly Isles. *By the* Rev. FRANCIS F. STATHAM, *B.A.*, *F.G.S.*

The author referred to the erroneous impressions which generally prevail with regard to the size, number and character of the Scilly group, which he described as presenting many features of interest independently of their curious geologic phenomena. It consists of a cluster of small islands or rocks 145 in number, varying in size from the mere solitary crag jutting out at low water from the surface of the ocean, to the Isle of St. Mary, which is the largest, the most populous, and the most fertile of the whole, measuring about 3 miles by 2½, and containing an estimated area of about 1640 acres. They lie in latitude 49° 57′ N., and in longitude 6° 43′ W., bearing W. by S. from Land's End, and due W. from the Lizard, from the former of which points they are distant little more than 27 miles in a straight line; though the distance from Penzance Pier (the usual starting-place for vessels from the main land) is about 40 miles to St. Mary's Pool. So far from being mere rugged rocks, these islands afford a pleasant home to between 2000 and 3000 inhabitants; the total population having been computed in 1851 at 2601 souls, the majority of whom dwell upon St. Mary's, though five of the other islands, viz. Tresco, St. Martin's, St. Agnes, Bryher, and Sampson, have a scattered population upon them nearly in proportion to their relative size. As the character of the rocks (being almost exclusively granitic) is very similar to that of the extreme promontory of Cornwall, it has been suggested by some writers that they may have been originally united with the main land; and traditions are not wanting of a very ancient date which might serve to confirm this opinion, were there not many countervailing reasons to be alleged in opposition. From the circumstance that the Gulf or Woolf Rock, which lies midway between Scilly and Land's End, is of *greenstone* and not of granite, and that in dredging the sea-bottom between these two points, shells and sea-weeds have been occasionally brought up clinging to *greenstone* or *clay-slate*, it is conceived that a tract of metamorphic rocks exists beneath the ocean between the mainland and the Scilly Isles, and that they are thus outliers only of the great granitic range of Devonshire and Cornwall. Many circumstances tend to prove that the conformation of the islands is very different now from what it has been even within historic times. Local tradition asserts that in former days there was a narrow causeway by which persons could pass across Crow Sound from St. Mary's to St. Martin's, and the ledge of rock which is visible at low water a little below the surface in this part is still called "the Pavement." Then again the Gugh, which in the time of Borlase (about 100 years ago) is described as "a part of Agnes and never divided from it but by high and boisterous tides," is now *always* an island at spring tides, and there is sufficient depth of water in the mid-channel for a boat to shoot across the bar. These considerations would seem to show that there has been a decided sinking of the land in these islands, even during the last century; and another fact which came to the author's knowledge while sojourning for a few weeks in the isles confirms this opinion. The masons who had been engaged in laying the foundations of a large warehouse belonging to Mr. Edwards, a short distance from the Strand, in the Pool of St. Mary's, when they had dug down several feet below the surface, came across the remains of former wooden buildings, which at one period must have been on a level with, if not above the sea, although at that time considerably below it. Possibly at no very remote period, geologically speaking, the whole of this group to the north, including Bryher, Tresco, St. Martin's, and the adjoining islets, have formed one continuous island, as the soundings even now between the contiguous portions are very shallow, and several of them can be reached from the others by walking over the bars at low water. With reference to the question of continuity at any former period with the mainland, Mr. Statham gave some curious particulars of the tradition respecting a tract of country called the "Lionesse," formerly alleged to have united Scilly with Cornwall, and referred to the junction of the slate with the granite at Marazion Bay, and also at a point immediately behind Penzance Pier. He had made diligent search throughout several of the islands to try and discover any traces of a similar collocation of rocks in Scilly; and although he had not found sufficient to warrant him in asserting the fact of a former continuity, he had met with unmistakeable proofs of the existence of clay-slate both on the Garrison Hill and on the top of Newford Down; which served to show that the Scillian group was more closely allied in the structure of its rocks to the formations on the mainland than had previously been supposed. The position in which the traces of slate rock were found were in a pit to the right of the path leading from the Star Fort on the Hugh, to the two dismantled windmills on the summit of the Down; and similar indications had presented themselves in a pit not far from the telegraph station at the summit of Newford Down.

The author next adverted to the different aspect of the islands as visited from the SW. or the N., where they are subjected to the wear and tear of the rough Atlantic waves, and to their smooth and rounded appearance when approached from the mainland. To the violence of the ocean, lashed into fury by the wintry gales, he attributed the craggy and rugged appearance of the rocks, the existence of caverns, and of proinent headlands in these directions; and he gave a singular exemplification of the power of water so agitated to alter the face of things by adverting to the fact, that in the Greater Crebawethan large boulders of granite, from half a ton to two tons in weight, have been lifted bodily out of the sea, and have been lodged in large heaps, as though the ballast of a dozen vessels had been piled upon the top of the island, probably 18 or more feet above the surface of the ocean at the highest spring tides. As the geologic features of St. Mary's seemed to be reproduced on a smaller scale in the other islands, the author next proceeded to give a detailed account of its most important characteristics. The various soils superimposed upon the granite in this island he described as the following:—1. A black surface soil composed of decayed vegetable matter, and in many places largely intermixed with sand, either blown up from the adjoining beach, or derived from intermixture with the underlying stratum. 2. A fine white ash-coloured sand, in some places (as in the pit just below the National Schools) containing fragments of shells imbedded in it. 3. A dark reddish or chocolate-brown clay, in many parts of considerable thickness, and having angular blocks of half-decomposed granite disseminated through it. 4. A stratum of loose grit or rubbly granite locally called "ram," sometimes so comminuted as to look at a short distance off like a bed of cream-coloured lime or sandstone, but more frequently coarse, and in the portions resting upon the granite mingled with large fragmentary masses of that rock; and finally, in the low and marshy ground, as at Holy Vale, and in the neighbourhood of Carnfriars, traces of a band of whitish pipeclay, the position of which ought most probably to be placed above the last-named deposit. The best locality for seeing at one view these various beds is a pit immediately below Mount Flagon, on the bridle-path leading towards Porthloo Bay. The beds here seen are numbered 1 to 5, downward. Between Nos. 3 and 4 the road-path intervenes, and No. 5 constitutes the low cliffs at this part of Permellin Bay. The stratum No. 2 seems to take its rise a little beyond Carn Morval Point, where it can be seen capping the cliff, which is here much higher, and running along the line of coast. It gradually thickens as it approaches St. Mary's Bay, where it assumes the greatest depth, forming in the neighbourhood of the National School, and in a section nearly opposite the Church, sand-pits of considerable depth, from which large quantities of sand are being continually carted for the purposes of ballast or manure. Other sections, precisely similar to the above, are to be found more inland, the most interesting of which is perhaps that in a pit by the side of the road at the Green leading towards New Quay. The stratum of sand here is not, it is true, more than 6 inches thick; but lying as it does under about 8 inches of soil, upon *one of the highest points* in the island, the section is valuable, as showing that in all probability, at one time the whole of the surface of the island has been capped with sand which has been washed away from those portions where it is now deficient, leaving the underlying stratum of brown clay visible. But there is another very curious geologic feature which will tell the same tale of the former submergence of the land, to allow of these arenaceous accumulations upon its highest points. Immediately behind the Guard House, inside the gateway of the garrison on the Hugh, is a kind of shallow cavern, which is now used as a place for storing lumber. The rough blocks of granite have fallen from the top of the entrance, so as to form a rude arch; and imbedded in the rock forming the sides of the entrance, are to be seen several large round boulders of granite, almost as regular as if they had been turned in a lathe, and compactly fixed in the matrix of the rock. Now this spot is considerably above the present level of the sea (probably from 150 to 180 feet), and the boulders of granite have all the marks of having been long rolled on a rough sea-beach. Moreover, the author was assured by the same masons as those referred to above (two brothers of the name of Williams), that they had been engaged in repairing the Guard House floor, and in digging beneath it they found other boulders of precisely the same character as those at the sides of the cave firmly imbedded in the soil. It is manifest then that the spot now adjoining the Guard House must once have been on a level with the surrounding sea, or at any rate at no great elevation above it, in order to account for the presence of these rounded boulders so deeply impacted in the solid rock. It becomes interesting therefore to inquire whether there are any traces of volcanic or subterranean action still visible in the islands, to which this upheaving of the land, after one, or it may have been frequent submersions, may be attributed. Mr. Statham entered largely into this part of his subject, and showed that several trachytic veins exist, which will partly account not only for the elevation of the land after its submergence beneath the ocean, but for the innumerable cracks or joints which are almost universally traceable in the granite of these islands. In the direction of the Causeway, which at low water joins Taylor's Island to the main land of St. Mary's, he had detected one such vein or dyke about 12 feet wide, and having the granite materially altered in character on each side of the erupted matter. To the existence of this dyke he attributed the alteration in the character of the granite on Taylor's Island, which exhibits crystals of tourmaline, replacing the mica. On the north side of Porthloo Bay likewise he had found at low water portions of a porphyritic ridge running parallel with the line of coast stretching out to Newford Island about N.W. by W. But by far the most interesting relic of igneous action in St. Mary's is to be found in the Elvan Course in Watermill Bay, near New Quay, to the N.E. of the island; and the author fully described it, and gave a detailed account of his theory for explaining the apparent stratification of the granite in the immediate neighbourhood. A description of several of the most striking groups of the rocks concluded the paper, with some curious facts as to the wearing action of the atmosphere and moisture in the direction of the joints in the granite, which had produced some extraordinary configurations, particularly at the Pulpit rock, the Tooth rock, Giant's Castle, and in Porth Hellick Bay.

On the Superficial Deposits of the Valley of the Aire at Leeds. *By* THOMAS P. TEALE, *F.L.S.*

In 1852 numerous large bones were discovered in the brick-earth nearLeeds, which, being taken to Mr. Denny, the able and zealous Curator of the Leeds Philosophical and Literary Society, were identified by him as the bones of the Hippopotamus. A fine collection of these bones, along with the remains of other mammalia, are now preserved in the Museum of this Society in Leeds.

The geological age of the deposit in which the bones were found became a question of great interest; and in the hope of contributing in some degree to its solution, I venture to offer the following observations to the British Association.

I have no hesitation in stating that the *Hippopotamus major* is the particular species found in the valley of the Aire. In this opinion I am confirmed by Mr. Woodward of the British Museum, and by Dr. Falconer. Of this animal, the Leeds Museum possesses the bones of at least four individuals of different ages and sizes. The skeleton of one of these is nearly entire. The vertebræ and cranium were found lying in their proper relative position, the ribs also, and the bones of the extremities. The bones had not the least appearance of being drifted or water-worn. Besides the bones of Hippopotamus, the tibia and portion of tusk, and some other bones of an elephant were found, but these are not sufficient to determine the specific form of elephant. The lower jaw of a gigantic ox, presumed to be the Urus, the jaws and horn-cores of smaller oxen, the horns of a large round-antlered deer, of a smaller deer, and the bones of a horse were also found in the same deposit. To determine the age of this fossiliferous deposit, it is necessary to take a survey of all those materials which overlie the outbreak of the coal formation in the Vale of Leeds.

These may be arranged under three distinct heads, each of which requires separate consideration:—1st. The blue clay, which is the oldest. 2ndly. The yellow clay. 3rdly. The warp, the newest in order of deposition in which the mammalian remains were found.

1. *The Blue Clay.*—In many localities is found a clay of a more or less blue colour on first being exposed, but becoming brownish or yellowish on exposure to the air. Wherever this blue clay is found in the Leeds district, it immediately overlies the outbreak of the coal formation. It occurs in irregular and isolated patches, often abruptly sloping off, and evidently showing that it owes the apparent irregularity of its distribution to the operation of denuding causes. It is seen in the Vale of Leeds at 140 feet above the sea-level; on the north of the river it is found at various elevations, up to the higher lands between the Aire and the Wharfe; for example, at Nether Green, at 175 feet of sea-level; at Woodhouse Moor, 300 feet; at Adel, 375 feet; at Yeadon Colliery, 420 feet. On the south, between the Aire and Calder, it is found at various elevations, and at Adwalton is seen at the elevation of 600 feet.

The rocky contents of this blue clay are of considerable interest, as they consist of rolled or far-travelled stones. At Nether Green, these are chiefly sandstones of great hardness, and of polished surface. At Woodhouse Moor, these hard rolled sandstones are in great numbers, and occasional masses of chertz from the mountain limestone. The nearest locality for this chertz is 25 miles, but it may probably have travelled 50 or 80 miles. At Adel, along with the hard polished sandstones, boulders of chertz and of mountain limestones occur. These must have been drifted over the higher ranges of land between the Aire and the Wharfe, and not swept down the valleys. Portions of trap-rock have also been found in the blue clay at Adel, and also a piece of red porphyry, which cannot have been derived from a nearer source than Westmoreland. At Yeadon the hard polished sandstones occur with abundance of chertz from the mountain limestone.

2. *The Yellow Clay.*—This clay is invariably found overlying the blue clay, wherever they co-exist, and resting on the coal-measures only in the places where they have been denuded of the blue clay. It is spread out more extensively than the blue clay, but like the latter, its distribution is irregular from the effects of denudation. It occurs low in the valley at Leeds, and ranges on the heights north and south of the Aire, to the elevation of 300 feet at Woodhouse Moor, 375 feet at Adel, 420 feet at Yeadon, and 600 feet at Adwalton; in all these localities it may be seen overlying the blue clay. At similar elevations it is often seen resting on the coal-measures, where they have been denuded of the blue clay. The yellow clay has much influence in modifying the features of the country near Leeds. It tends greatly to soften the harshness of outline which the abrupt outbreaks of the member of the coal formation would have occasioned.

The rocky contents of the yellow clay are particularly deserving of notice. These stones, often of large size, are for the most part angular or subangular, derived from rocks in the neighbourhood. These are not *far-travelled* stones, but still they are *travelled* stones, and are not resulting from the mere disintegration of the rocks *in situ* from aërial causes. This may be proved by an examination of such stones in the yellow clay as can be identified with the parent rock. A good illustration of this occurs at Headingley, in the grounds of Mr. Hewitson, who kindly directed diggings to be made to assist me in these investigations. In one of these the yellow clay, 8 or 9 feet thick, rested on the sandstone shale of the coal formation. At this place the clay contained great numbers of stones, known as "calliards." These are sandstones of great hardness, occurring generally in masses of subrhomboidal form. The bed of rock which furnished these calliards is well known in the district, and has its outbreak from a quarter to half a mile north of Mr. Hewitson's diggings. The stones therefore must have travelled this distance. These stones have had the sharpness of their angles somewhat blunted; they vary in size from a few inches to 2 or 3 feet. Along with these calliards, in the same clay occur great numbers of stones of millstone grit, somewhat more rounded than the former, but not polished by long travel. These stones are easily recognized as being derived from the parent rock at Weetwood, where we find a bed of very coarse millstone grit, easily disintegrated, having its outbreak from half a mile to three-quarters of a mile north of Mr. Hewitson's. Similar observations might be made in reference to other known rocks of the district occurring in the yellow clay.

3. *The Warp.*—Under the name of warp, I would describe the true valley deposit of the Aire at Leeds. The deposit is familiarly known to the workpeople of the district under this name.

In position, the warp overlies the yellow and the blue clays whenever the three co-exist. It is frequently seen resting on the yellow clay, or resting on the blue clay when it has been denuded of the yellow, or resting on the coal-measures where they have been denuded both of the blue and yellow clays. At Dickens Street, New Wortley, it occupies a trough formed by denudation, resting on the yellow and blue clay on each side, and on the coal-measures in the middle. At Beeston Vale it rests successively on the yellow clay, the blue clay, and the coal-measures; a similar arrangement is observed near Sheepscar Bar, and in other localities. The warp is spread over the valley of the Aire, producing a flat-looking surface, gently sloping upwards at the sides of the valley, and downwards towards the estuary. At the sides of the Vale of Leeds, the warp shelves off a little below the sea-level of 150 feet, and is not found higher than this level in the immediate neighbourhood of Leeds. Prolongation of the warp may be traced up all the little tributaries of the Aire in this district as high as to the level of 150 feet, or thereabouts.

The characters of the warp deposit are very variable. It sometimes approaches to a tolerably pure blue or yellow clay, but generally it is much more earthy and dirty-looking than the clays before described. In many localities it is very sandy, and indeed passes into sand and gravel, more especially in the central parts of the valley. It contains stones of very variable character, some angular and subangular, derived from no great distance; others rounded, polished, and far-travelled. It contains much vegetable matter, as roots and fibres. Drifted wood, chiefly oak, is found in great abundance in it; also the fir, the hazel, and abundance of leaves and nuts. In the vestibule of the Leeds Museum is the trunk of a riven oak tree, split as if by lightning. This portion of tree was found in the warp at New Wortley, and bears evidence of the violence to which it had been subjected. The remaining portion of the tree was not to be found in the neighbourhood.

In its composition, the warp appears to exhibit an irregular commixture of displaced blue and yellow clays, with their peculiar rocky contents, and also of a surface earth and its abundant vegetation.

If I may be allowed to speculate upon the cause of displacement and rearrangement of these materials, I should attribute them to a gigantic land-flood, similar to what we now occasionally witness, but more intense and more prolonged. By such a flood, it may be presumed that the river was raised from its ordinary sea-level of 60 feet to an elevation of 150 feet, displacing extensively within its range, the blue and yellow clays, and surface earth, and vegetation; bringing down from the upper parts of the Valley of the Aire, abundance of sand and gravel, commingling and rearranging these varied materials, forming a flattish valley surface shelving off at the sides about the level of 150 feet, overlying the blue and the yellow clay where they exist within its range, and overlying the coal-measures where they have been denuded of the clays.

In this deposit were found the remains of *Hippopotamus major*, an elephant, a gigantic ox, and a smaller ox, and other animals probably identical with existing species.

The *inferences* which I draw from the facts now recorded are,—

1st. That the blue clay, overlying the outbreak of the coal formation, containing far-travelled stones, and occurring at various elevations as high as 600 feet, is the Glacial Drift of submergence.

2nd. That the yellow clay, overlying the blue, occurring at the same elevations, containing travelled, but not far-travelled stones, is the Glacial Drift of emergence, occurring under a gentler current than the former.

3rd. That the warp, overlying the blue and yellow clay when they co-exist, and resting on the coal-measures when they are denuded of the clays, not ranging higher than the sea-level of 150 feet, containing the bones of extinct mammalia, is a newer deposit than the glacial drifts.

4th. That the *Hippopotamus major* and an elephant existed in these lands subsequently to the Glacial Age.

On the Fens and Submarine Forests of Lincolnshire and other Localities. By the Rev. Edward Trollope.

The author observed, that a great contest between the sea and land, leading to frequent changes in their respective boundaries, had certainly been raging upon the Lincolnshire coast for centuries before the arrival of the Romans in Britain, and that period when written records began to be kept. The ocean had from time to time swept far beyond its natural limits, and yet little by little it had, by its very fury, aided to form a future barrier against itself by the accumulation of the silt left upon its retreat, in concert with the earthy deposits caused by the continual flow of the inland waters. At one time the sea had lorded it over a considerable portion of the Lincolnshire coast, but afterwards fresh water became in the ascendant, and had left the mark of its reign behind it in the form of soapy blue clay, varying in tint, and abounding in fresh-water shells. The ocean, however, occasionally gave battle to the fresh water, as was shown by the existence of channels filled with marine silt running up into the blue clay. In this stratum grew up trees of various kinds, as oaks of vast size, firs, alders, birch, and hazels, whose roots were yet firmly fixed in the soil, while their innumerable trunks lay prostrate beneath the black peaty earth composed of decayed vegetable matter. It might safely be assumed, that the period of the growth of these trees lasted for five centuries. How long these fen districts continued to be covered with stagnant fresh water after they had wrought such terrible ruin upon thousands of acres of the finest forest lands, was not deducible from any internal evidence; but they certainly were for the most part still prevalent when the Romans appeared upon the scene. They proceeded to encircle the coast with a vast sea bank, to deepen and defend the outfalls of the rivers, and to construct drains. But besides the coastal line of fen-lands, there were vast tracts in the interior of Lincolnshire of a similar character, forming in the aggregate 522,000 acres, lying from 4 to 16 feet below high-water level. The largest of these extended from the Trent, through the isle of Axholme, into Notts, and far into Yorkshire, in the direction of Doncaster. It might fairly be assumed, that during the Roman occupation, this vast tract of fen-land bore quite a different character to what it had since done; that it had a gravelly subsoil, and an ordinary earthy surface, covered with trees; not usually, if at all, subject to floods; but that subsequently it became more or less constantly submerged, so as to destroy its previous forest growth, and to cover the bodies of the former vegetable giants of the district beneath an earthy deposit. This great change had usually been attributed to the burning of the forests by the Romans, on account of the covert which they afforded to swarms of suffering Britons. There were apparent signs of burning about the stumps of some of the trees, but others had clearly been cut down, and many had been torn up by the roots. The felled trees would never so have impeded the flow of the inland waters as to convert an immense district of previously dry land into a permanent swamp, as had been suggested; he would therefore endeavour to find another solution of this difficulty in connexion with a still more remarkable fact, namely, the existence of the remains of a submarine forest off the present Lincolnshire coast. Along the shore of that county, from Sutton to Cleethorp, many banks or islands were from time to time exposed to view. These were usually covered with silt, but when occasionally stripped of that marine deposit, they were found to possess a substratum of moory vegetable soil, filled with the roots and prostrate trees of very large size, accompanied by their berries, nuts, and leaves. Two questions arose in connexion with these facts, namely, When were these districts severally submerged by fresh and salt water? and by what agency? Various theories had been advanced for the purpose of solving these problems, the principal of which were :—1st, the interference of the Romans with the natural drainage; 2nd, a change in the coastal line through the action of the sea; 3rd, the agency of earthquakes causing subsidence of the earth. The author examined in succession each of these theories, and gave his opinion in favour of the last. He referred to the existence of other submarine forests at various points of the shores of Scotland, England, and Wales. He observed that this theory might seem to be more marvellous than the preceding ones, and therefore less likely to be true in the opinion of those who were unacquainted with geology; but when, from the study of that science, they found that certain strata, the undoubted deposit of water, were now upheaved far above the reach of that element, and that large tracts of land had sunk beneath it, they could only regard such changes as one of the usual, but always wonderful operations of nature.

The author cited other instances of similar phenomena, and in conclusion said that he was inclined to think that a slow upward movement had begun to take place in large districts of Lincolnshire long ago, and that by means of carefully conducted scientific observations this would hereafter be certainly proved and accurately measured. The filling up of channels and estuaries of large size that formerly existed, and the rapid growth of its coast at various points, apparently indicated this; while the known gradual but continually increasing elevation of the Danish coast and parts of Norway greatly strengthened such a supposition.

BOTANY AND ZOOLOGY, including PHYSIOLOGY.

Botany.

Mr. Baines, of York, exhibited a bunch of grapes, which presented the peculiarity of black and white grapes on the same bunch.

On the Geological Distribution of Plants in some Districts of Yorkshire. *By* Dr. Carrington.

The chief tract taken for illustration was that part of Craven included between Gordale and Kingsdale, and cut off on the south by the magnificent line of scars known as the Craven fault. The physical and geological peculiarities of the district were minutely described. The origin of the present vegetation was referred to different periods; the more ancient portion, including plants of boreal type, being probably a remnant of the Pre-Glacial Flora. The species found in Craven are 600 flowering plants, and about 500 mosses and lichens.

After considering the present state of our information as to the geognostic relations of plants, the following classification of strata was recommended, each group being characterized by a peculiar Flora:—1st, Calcareous formations, highly absorbent, acted on by the elements chemically rather than mechanically (the carbonic acid in water dissolving the lime), forming a dry, scanty, but fertile soil; 2nd, arenaceous formations, disintegrating freely, and producing an abundant sandy deposit, on a large scale, forming absorbent, barren stations; 3rd, argillaceous formations, subject to rapid abrasion, forming clayey deposits, comparatively impermeable and hygroscopic. In practice we find these often mingled together, *e.g.* shales with sandstones; and the soils frequently differ in nature from the rocks they cover, having been derived from distant sources. The practice of agriculture has especially tended to mingle and equalize the soils of various districts.

The prevailing rock of Craven is the scar limestone. It supports the greenest of pasturage, and most of the rare species are found on it, e. g. *Actæa spicata, Draba incana* and *D. muralis, Cardamine impatiens, Hutchinsia petræa, Hippocrepis comosa, Dryas octopetala, Saxifraga oppositifolia, Hieracium Gibsoni, Bartsia alpina, Primula farinosa, Epipactis ovalis, Cypripedium calceolus, Lastrea rigida*, and many characteristic mosses and lichens; the latter deserving especial notice from growing directly on the rocks. The prevailing lichens are species of *Collema*, such as *C. nigrum, stygium, fluviatile*, &c., *Parmelia crassa, P. calcarea, Lecidea lurida, candida, immersa, saxatilis, calcarea*, &c., *Verrucaria immersa, Gagei, Dufourii, plumbea*, and *epipolæa*. The sandstones are restricted to the millstone-grit, capping Ingleborough and other summits, upwards of 2000 feet high. They are covered by a coarse brown vegetation of ling, heath, crowberry, bilberry, *Juncus squarrosus*, &c. The lichens are brown and golden coloured, *e. g.* species of *Umbilicaria, Parmelia atra, olivacea, saxicola, badia, murorum, Lecidea lapicida, confluens, prominula, fusco-atra*, and *rupestris*. The argillaceous rocks are represented by the Yoredale shales and Lower Silurian slates, exposed in Ribblesdale and Chapeldale. They afford damp, dripping stations, supporting a scanty glaucous vegetation of Equiseta, rushes, and Carices, e. g. *Sedum Rhodiola* and *S. Telephium, Saxifraga aizoides, Carduus heterophyllus, Equisetum hyemale* and *variegatum, Allosorus crispus, Hymenophyllum Wilsoni, Scolopendrum ramosum*, &c. Lichens: *Parmelia conspersa, P. sulphurea, Sticta herbacea, sylvatica, scrobiculata, Nephroma, Lecidea confervoides, geographica, polytropa, rivulosa*, and many others.

Dr. Heaton exhibited to the Section a specimen of a plant, which bore on the same branches the characteristic leaves of two distinct species of *Cytisus*.

Researches on the Colours of Leaves and Petals. *By* W. E. C. Nourse, *F.R.C.S.*

In a paper published by the author in the 'Annals of Natural History' for 1845, it was shown that immediately beneath the cuticle of leaves and petals is a layer of cells of small size, circular form, and variable colour, which is named the *Rete*. The central layer of leaves and petals, consisting of veins and larger cells, is called the *Substance*. In petals, the rete contains the colours, the substance being nearly or quite colourless. In leaves, the substance contains the great mass of green colour, the rete superadding the dark tints and marks. The present paper contains further observations by the author.

1. Eight instances of leaves were examined during the autumnal change of tint. The change invariably begins in the rete or layer of cells immediately beneath the cuticle, whether upper or under; and extends subsequently to the substance. The rete is thus the principal seat of the brilliant autumnal tints of leaves. When the change begins on the upper surface of the leaf, it is first seen at the edges and in the intervenous spaces; when on the under surface, it is first observed in the centre, and in contact with the principal veins.

2. The examination of numerous kinds of variegated leaves showed that variegation is invariably thus produced: the young leaves are unfolded of one uniform tint; then, when they are about half-grown, a patch of some other tint is developed on the upper surface, in the centre, and in contact with the principal veins. Variegation thus obeys an opposite law to that which regulates the autumnal tints and the accidental markings of leaves. It is, furthermore, of two different descriptions; in one, the edges are white and the centre green, the young leaves having been unfolded in a state of quasi-etiolation, and patches of green being afterwards developed in the centre; in the other, the edges are green and the centre yellow, the young leaves being green, and yellow patches being afterwards developed near the midrib. In both descriptions, in the green parts of the leaves, the rete, or layer of cells just subjacent to the cuticle, affords, as usual, the deepest green, the substance being of an ordinary green all through; and in the light-coloured parts, the rete contains whatever colour is presented, the substance being whitish all through.

The patch thus developed, in one case yellow, in the other case green, begins to appear only when the leaf has attained some growth, and has consequently exercised its vital functions for some little time in contact with the atmospheric air. Then, not at the edges, like chance markings or the tints of incipient autumnal decay, but in the centre of the leaf, and therefore in contact with the principal veins, appears on the upper surface the patch, of either colour, and from those veins it spreads. Hence it is inferred, that the colouring matter in these patches, whether green or yellowish, is in a high and vigorous state of development, quite different from those tints which approximate towards decay. An accurate microscopical and chemical examination of the cells and their contents, both of rete and substance, in the light-coloured portions of variegated leaves, as contrasted with the green parts, is a desideratum.

3. Of the ordinary tints and markings of leaves, eight special instances were examined; proving that the substance is of a green colour which is very nearly uniform in all leaves, and that the rete is the seat of the extra tints and markings. In regard to the veins and surfaces, these extra colours are invariably in one of two situations; either in contact with the principal veins, and in such case most conspicuous on the under surface of the leaf; or else quite away from the veins, occupying the intervenous spaces and edges of the leaf, and then mostly seen upon the upper surface. They thus obey the same law as the autumnal tints, and are probably of similar nature; contrasting remarkably with the law above stated which regulates variegation.

4. Numerous specimens of petals were examined, showing the absence of colour in the cuticle and substance, and the localization of the brilliant colours in the cells lying just beneath the cuticle, here called the rete. The most highly coloured cells are generally the smallest, always lie densely packed together, and are commonly roundish, sometimes elongated.

5. The anomalous organs in half-double flowers, partly stamen and partly petal, suggested to the author that the pollen seemed to take the place of the coloured cells of the rete; and that the cells of the rete in leaves and petals, became, in stamens, the pollen-grains. Sundry specimens were therefore examined, to ascertain how far the shape and size of the pollen-grains bore any relation to those of the cells in the

rete; but no resemblance could be made out. This theory has yet to be confirmed or superseded by further research. The floral envelopes stand in mid-relation to two other sets of organs. Without, we find their analogues in the bracts and leaves; within, they are represented by the stamens. We have thus, in an advancing order of perfection and delicacy of organization, first the leaves; then the petals; finally the stamens,—organs long known to be mutually analogous, and, within certain limits, mutually convertible:—the leaves, the organs most concerned with the nutrition of the individual; the stamens, most concerned in reproducing the species; and the petals, organs intermediate, both in place and in physiological relation, between the two. In the leaves, the brightest colours, both in life and decay, obey like conditions, and are alike contained in those subcuticular cells named the rete; while the great mass of the ordinary green colouring of the leaf is contained in the cells of the substance. But in petals the substance contributes very little to the colours, and the rete assumes a more prominent importance, and stands out as a more distinct structure. Here, more nearly approaching to the organs of reproduction, the cells of the rete display every conceivable variety and vividness of colour, besides being smaller and rounder than the cells of adjacent tissues. Now if it could be shown that, in the stamens, the cells which in a petal would form the rete, take on a further and more advanced development, with novel functions, and become the pollen, we should then understand more clearly the meaning of the brilliant colours displayed in the petals, and should recognize the rete-cells both in petals and leaves, as constituting a more important structure than at first appeared. We should be reminded of the connexion, in the animal kingdom, between brilliant colours (so connected with the dynamic effects of light) and the function of reproduction; as well as of those instances in which the decay of the individual bore a relation to the perpetuation of the species, or in which the latter function was held in abeyance by the over-nutrition of the individual. So, it is at the commencement of decay that the leaves most simulate the bright colours of petals. So, by cultivation we over-nourish a plant, and bring about significant changes: first, the pollen disappears, and each stamen becomes developed into a coloured petal, which increases as we continue to nourish; then, as we proceed further, the plant refuses to flower at all, and instead of petals, are produced leaves; and instead of flower-like whorls, tissue is developed between them, and they stand apart as leaves.

Should this view be confirmed, it might be worth while to extend the examination to *Ferns*, to see whether the coloured particles of the rete do not become spores, the cuticle forming the covers. The highly coloured and organized cells of a rete, in plants of that lower stamp, may pass directly from the condition of leaf-colour to that of the seed-particles of the species, without requiring the complicated intermediate states and processes necessary in higher organizations. On casual inspection of fronds, in various stages of fructification, the opening covers certainly look like the splitting cuticle, gaping at those parts to give exit to the swollen and changed granules of the rete.

Finally, there remains to be investigated the nature of the changes in colour both in leaves and petals which are wrought in contact with the veins, and the differences between them and those which are produced apart from the veins; the further conditions affecting variegation, both in leaves and petals; and the nature of those petal-colours which are produced in the unfolded bud, independently of the influence of light, and the respects in which they differ from ordinary petal-colours.

Mr. S. Smith exhibited to the Section some balls about 3 inches in diameter, composed of the hairs of a plant which he had picked up on the shores of the Mediterranean.

On Suburban Gardens. By N. B. Ward, *F.R.S.*

The author commenced his paper by describing the impressions made upon him in early youth, in a voyage to Jamaica, by the glorious aspects of the sea and sky, —the dolphins playing about the bows of the vessel,—the flying fish alighting on its deck, and the occasional sight of an albatros,—the tropical forms of vegetation on the beach and the hills,—and the mighty world of wonders on the coral reefs.

On his return to London he stated the great advantages he had received by accompanying the Professor of Botany, under the patronage of the Society of Apothecaries, in repeated herborizations round London, which gave him a great insight into the natural conditions of all the plants within twenty-five miles of London. On his establishment in Wellclose Square, he endeavoured to fulfil these conditions in a kind of terraced garden on the roof of his brewhouse, but with indifferent success. This garden was destroyed by fire. A subsequent attempt to grow ferns and mosses proved equally unsuccessful from the influence of smoke. An accident led him to the employment of cases sufficiently close to exclude soot and other impurities, and to retain the moisture. The first important application was the conveyance of plants to and from distant countries, which proved so successful as to be universally adopted. On his removal to Clapham he found that he was enabled to grow great numbers of plants in the open air by supplying them with proper food, &c.; and therefore restricted the use of the closed cases to such plants as could not with all his care be cultivated in the open ground. He expressed his belief that the cause of failure in the cases arose, not, as had been stated, from the quiet condition of the atmosphere, but from the much greater heat of the case when exposed to the summer sun without a blind, the thermometer often rising from 20° to 25° higher than in the open air. When the sun is obscured the temperature in the cases is not more than from 2° to 15° higher. It is his firm opinion, that where the natural conditions as regards heat, light, moisture, soil, and periods of rest are fulfilled, the undisturbed state of the air, so far from being prejudicial, is of great service. This fact he has proved with numerous plants; and he will feel extremely obliged to those who will kindly communicate instances to the contrary. What strengthens his conviction that heat is the cause, is the fact that in the spring and early summer months no cases of failure arose. He exhibited, among other plants, specimens of two fairy roses, the one having been in a case for three or four years, and the other above twenty.

On some Practical Results derivable from the Study of Botany. *By* N. B. WARD.

The author commenced his paper by observing that Botany had not had fair play, and that in many ways it might be rendered a much more attractive and useful science. In the formation of an herbarium, for example, he considered that such a collection might, in numerous instances, give a faithful, and if faithful, a beautiful picture of nature. This position he illustrated by a series of specimens from the Dovrefeldt range of mountains in Norway, and arranged in three different ways,—all of them conveying useful information :—first, the association of such plants as grow together, illustrated by a sheet containing forty or fifty species of plants from the highest portion of the range—on the borders of eternal snow; secondly, the grouping of plants belonging to one natural family, as the Ericaceæ; and thirdly, the arrangement of one or more genera according to their elevation on the mountain side, illustrated by four species of Saxifrage, one of which grew at 3000 feet elevation, one at 4000, one at 5000, and one at 6000 feet, respectively.

He further remarked that the climate conditions of plants might be most unmistakeably shown by observing the spontaneous vegetation of hedge banks, &c., and this was exemplified by a series of specimens from the banks surrounding the timber plantations in the New Forest, and from a bank near Tintern Abbey, Monmouthshire, the former indicating a moderate, the latter an excessive amount of moisture.

He then proceeded to urge the importance of cultivating a taste for legitimate horticultural pursuits among the members of the labouring population, as it was a well-established fact, that "whenever a pink, or a carnation, or rose was seen outside a cottage, there was a potato or a cabbage for the pot within; that if there were not happiness, there was the nearest approach to it in this world, content."

"Yes, in a poor man's garden grow
Far more than herbs and flowers;
Kind thoughts, contentment, peace of mind,
And joy for weary hours."

He concluded by a communication he had received from the Bishop of Ripon on the preceding Sunday, and which was, indeed, his principal reason for again appearing before them. The communication of the Bishop was to this effect:—"The parish of Arncliffe, near Skipton, in Yorkshire, situated in a very wild part of the county, and inhabited by a wild and lawless tenantry, had been for many years without a resident clergyman, the living being a very poor one—not above £30 a year. The present incumbent, the Rev. Mr. Boyd, determined, however, to set himself down among them and to use his utmost exertions in bettering their wretched condition. To this end he surrounded his house with a fine garden, well-stocked with lovely flowers, and induced his peasantry—but with great reluctance—to come in one by one to see and admire his flowers, and to take them home and cultivate them. Now for the first time they had light in their dwellings, and ultimately, through the kind and constant personal care which was bestowed upon them, have become the most contented and happy set of villagers in all Yorkshire."

On the Epidermal Cells of the Petals of Plants. By Tuffen West.

The author, in working on microscopic subjects, generally had his attention arrested by that well-known object the petal of the geranium, and being unable to recocilen its appearance with the descriptions found in books, was led to the investigations now communicated to the Section.

After detailing his observations on the epidermis of the petals and the hairs of a variety of plants, he came to the following conclusions :—1. The prolongation of the outer cell-wall of the cuticle of petals into mammillary protuberances is a usual condition; such elevations being, with rare exceptions, most marked on the inner surface, and being hairs in a more or less rudimentary condition. 2. That the markings on the parts here named (which may be divided into two kinds, lines and dots, though examples of an intermediate nature occur) are both caused by corrugation of the cell-wall, and not by external secondary deposit upon it.

Zoology.

On the Reproductive Organs of Sertularia tamarisca. *By* Professor Allman, *M.D., F.R.S.*

The author called attention to the fact, that *Sertularia tamarisca,* which, like most of the Hydroid Radiata, is strictly diœcious, presents the further remarkable character of having its male and female gonophores (generative vesicles) totally different in form,—an important fact, as regards the zoographical characterization of the species.

The male gonophores appear to be those figured by Ellis in his description of this species; they are compressed, somewhat obcordate bodies, with a short terminal tubular aperture.

The female gonophores are far less simple in form; they are oval for about the proximal half of their length, and then become trihedral with the sides diverging upwards, while the whole is terminated by a three-sided pyramid. The sides of the pyramid are cut into two or three short teeth along their edges, and each of their basal angles is prolonged into a short spine.

The trihedral portion, with its pyramidal summit, is formed of three leaflets, which merely touch one another by their edges without adhering, so that they may be easily separated by the dissecting needle. They consist of the same chitinous material as that which invests the rest of the gonophore, formed doubtless originally on the surface of an ectodermal lamina.

The male gonophore is traversed by a fleshy axis (blastostyle), which gives origin to one or more sporosacs containing the spermatogenous tissue surrounding a well-developed spadix*. The spermatozoa have an elongated body of a cylindrical form, with a long caudal filament.

* The author proposed the term *spadix* to indicate the diverticulum from the common cavity of the cœnosarc, which in most of the Hydroid Zoophytes extends into the centre of the sporosac, and round which the generative elements (ova or spermatozoa) are developed.

On laying open the female gonophore, the oval portion of it is seen to be occupied by a blastostyle, which gives origin to one or more sporosacs entirely resembling the male sporosacs except in the nature of their contents, which are here ova instead of spermatozoa.

The oval portion of the gonophore terminates upwards by closing round the remote extremity of the blastostyle, where it forms a ring with tooth-like processes by which the extremity of the blastostyle is encircled. This oval portion constitutes the proper capsule of the gonophore, and is the only part developed in the male. From the summit of the blastostyle several irregularly-branched cæcal tubes, apparently communicating with its cavity, are given off. They lie altogether external to the proper capsule, and embrace a delicate sac, within which are one or two ova in an advanced state of development, each in a delicate structureless sac of its own, which is continued by a narrow neck towards the summit of the proper capsule, with whose cavity it would seem to communicate; but the author did not succeed in tracing its connexions beyond this point.

These ova, with their investing sacs, and the surrounding cæcal tubes, would thus lie entirely exposed, were it not that they are surrounded by the three leaflets already mentioned as constituting the trihedral portion of the gonophore. These leaflets are given off from the oval portion or proper capsule near its summit, and being in contact by their edges, completely enclose a space which is occupied by the structures just described.

These structures are thus truly extra-capsular, and correspond with the extracapsular ovigerous sacs which occur in *Sertularia pumila*, *S. cupressina*, and other species, and into which the ova are conveyed from the interior, to undergo, as in a sort of *marsupium*, a farther development previous to their final liberation as embryos.

With regard to the true import of the sporosacs and their relation to the Medusoid buds produced by other Hydroids, the author insisted on the necessity of bearing in mind that the spadix has no ectodermal covering, and consists of endoderm alone. He considered it to be homologous with the manubrium ("peduncle") of a Medusa separated from its ectoderm by the intervention of the generative elements, which in the sporosac are always found between the entoderm and ectoderm of an organ strictly homologous with the so-called "peduncle" of a Medusa. By the continued growth of the generative elements, the ectoderm is separated more and more from the endoderm, which now constitutes a diverticulum from the cavity of the blastostyle, enveloped by the ova or spermatozoa; while the ectoderm forms the walls of a sac which immediately confines these elements. The whole is enclosed in an external sac, which seems to be an extension of the ectoderm of the blastostyle.

We have thus, in the sporosac of *Sertularia tamarisca*, an organ which easily admits of comparison with the Medusoid buds of other Zoophytes; it consists, in fact, of a manubrium peculiarly modified, so as to constitute a sac for the retention of the generative elements, and chiefly differs from the proper Medusoid buds in the non-development of a swimming organ or umbrella. In other instances (*Cordylophora*, &c.), as the author has elsewhere shown*, peculiar cæcal tubes, generally more or less branched, are developed from the base of the spadix, and thence extend, along with the ova or spermatozoa, between the ectoderm and endoderm towards the summit of the sporosac. The author had already compared these tubes to the radiating gastro-vascular canals of a Medusa; and if this comparison be just, they remain in the sporosac as the sole representatives of the parts found in the umbrella of a Medusa†. A change of position, however, has taken place, and the radiating canals, having withdrawn themselves from the covering of ectoderm which they possess when forming a constituent part of the developed umbrella, are now composed of endoderm alone, and lie between the endoderm and ectoderm of the manubrium, where they form cæcal processes from the spadix or endodermal portion of the manubrium.

* Phil. Trans. 1853.

† In a paper by the author on *Cordylophora lacustris* (Phil. Trans. 1853), he expressed his belief that the umbrella of a Medusa had its representative in the walls of the sporosac; subsequent examination, however, of the sporosacs in a great number of species had caused him to modify this view and adopt that contained in the present communication.

Remarks on the Migration of Birds.

By CUTHBERT COLLINGWOOD, *M.B., M.A., F.L.S., Lecturer on Botany at the Liverpool School of Medicine.*

The author began by remarking upon the extreme interest of the phenomena of migration to the ornithologist, and the simplicity of the general plan, which had been unnecessarily complicated by the supporters of the now exploded doctrines of hybernation and submergence. The fact that those birds which winter here (except in those very rare cases which prove the rule) never breed with us, is the true key to those phenomena. The fieldfare and redwing are impelled northward in April, by the same impulse which brings the nightingale and blackcap to us from the South. All retire from the advancing sun in spring; and all seek those spots where they themselves first saw the light, there to rear their young. This business ended, they again retire to regions more constitutionally fit for them in the dead season. The sun, therefore, is the great moving power, and the equinoxes the signals for migration. A sexual impulse, arising from the development of the reproductive organs, drives them before the advancing sun in spring,—a failure of temperature and food, added to that of the reproductive stimulus, makes them follow the retiring sun in autumn. The author suggested, arguing from the analogy of the short internal migrations of some British birds, that the period of time during which a bird remains in this country in summer might be taken as an index of the distance southwards to which he retires for the rest of the year,—that the chiff-chaff, for example, which spends fully six months of the year with us, retires to a much less distance in winter than the swift, which remains absent from us nine months out of the twelve. The conditions under which birds exist in warmer latitudes in the winter season, are probably the same as regulate those which remain, the only difference being one of constitution or hardihood; that is, that our birds of passage require the higher temperature, simply to keep them in the same state of active life which our indigenous birds maintain under our wintry skies. As an example of these conditions, the fact that, of our migratory birds, the males arrive usually a week or ten days in advance of the females, seems to show that a separation of the sexes takes place with them, such as is so common a phenomenon with our indigenous birds at that season. That the migratory birds arrive in full song, the author was convinced from observation, it having frequently happened that a careful watch for their first appearance had been rewarded at length by hearing just so much of their note as was sufficient for one well-acquainted with it to recognize them; but on the following day the woods were resonant with the perfect notes of the very same bird. The recurrence of this observation had convinced him that fatigue alone had been the cause of their mutilated song the previous day. Attention was next directed to the great discrepancy which existed between the mean date of arrival of the summer birds of passage, as given by different ornithologists. The mean dates given by White, Markwick, Jenyns and another for twenty-five summer birds of passage were presented in a tabular form, and exhibited a variation of as much as a month or six weeks for the same bird. This arises probably from the fact, that the experience of a single individual is liable to fallacy,—that he may not have the same opportunities of accurate investigation in two consecutive years: consequently, certain dates in a series of observations are much too late; and these, when reduced to a general mean, destroy the balance of the whole. A comparison of the earliest dates given by seven ornithologists, for the same twenty-five birds, gave much more equable results, because probably *that* observation was made under the best circumstances, and therefore most in accordance with truth. Still, however, there was something to be accounted for,—some influence which in certain seasons somewhat accelerated them, and in others retarded them. The question arises, whence does this influence arise? Surely not at the point for which they are making, but rather at that from whence they are setting out. We should not expect, therefore, that birds would necessarily arrive sooner in a forward season, nor later in a backward one; and experience proves, what reason would suggest, that the actual temperature of our spring is not intimately connected with the earlier or later appearance of the migratory birds. The author, however, purposed making a more careful comparison between the records of the arrival of the birds, and the meteorological indications, than he had been able to do hitherto, with a view to elucidate this subject. With regard to the destination of our summer birds in winter, a large series of direct experiments was necessary to the proper comprehension of the length and direction of the lines which they followed.

Some Observations on the Fishes of the Lake District. *By* J. Davy, *M.D.*, *F.R.S.*

In this paper the author referred,—1st. To the species of fish hitherto known in the district. 2nd. To their habitats, remarking that one of them, the vendace, till recently supposed to be peculiar to Scotland, had been found in Derwentwater. 3rd. On the causes of the distribution of fishes; taking the vendace in its limited range as an example, two theories in explanation were offered as most probable,—one, the transportation of its ova by birds, the other by floating ice,—their vitality not being destroyed at the freezing-point of water. 4th. The growth of fish, of which remarkable instances were recorded, under the influence of unstinted and fitting food. 5th. Of variations in the species, occasioned by different agencies. The paper concluded by pointing out the necessity of legislative interference to prevent the destruction of fish. They are now taken in largest quantities at the season when they are about to deposit their ova, and when least fit for food. A closed season should be instituted throughout the country, and parr and smolts should never be taken.

On the Cause of the Instinctive Tendency of Bees to form Hexagonal Cells. *By* R. L. Ellis.

The author supposed that bees were led to the exercise of this instinct by the use of their organs of sight. It was well known that, in addition to their facetted eyes, they had three single eyes; and he supposed that these eyes were placed in such a position as to enable them to work within a range sufficient to give the walls of their cells dihedral angles of 120 degrees.

On the Arrangement of Birds. *By* T. C. Eyton, *F.L.S.*

The mode in which birds obtain their prey is subject to considerable variation: adapted to this variation are the various members and organs of the class. The principal modes in which birds obtain their prey are the following:—By the power of flight or direct chase; by the power of approaching their prey unobserved; by the power of climbing; by the power of scratching and running; by the power of wading, and by the power of swimming. If a division of birds is made strictly according to the above qualities, there will be many that will not conform strictly to the greatest perfection of development adapted to each mode of living, but are endowed with a modification or mixture of two or more of them. Mr. Eyton proposes to divide birds into the following orders:—1. Raptores, or birds of prey, containing the families Vulturidæ, Falconidæ, and Strigidæ; 2. Noctivores, or night-feeding birds, containing the Caprimulgidæ, Trogonidæ, and Coracinidæ; 3. Volitores, or flyers, containing the Trochilidæ and Cypsilidæ; 4. Lapsatores, or gliders, containing the Alcedinidæ, Buceridæ, and Upupidæ.

Prehensores or Parrots.	Cursores or Runners.
Scansores or Woodpeckers.	Rasores or Scratchers.
Erucivores or Cuckoos.	Littoreals or Shore-birds.
Insessores or Perchers.	Grallatores or Waders.
Bipositores or Pigeons.	Natatores or Swimmers.

Mr. Eyton called the attention of the meeting to the peculiar mode in which the coracoid bone is articulated to the sternum among the humming-birds, and exhibited a drawing and specimens of those parts.

On the Oyster. *By* T. C. Eyton, *F.L.S.*

At the Cheltenham meeting the author exhibited the young oyster taken from the beard of the parent. He now traced the young oyster from the embryo state in the ovary to its perfection at five years old; and exhibited a series of drawings on the history of the oyster, the mode of preserving the beds and increasing their productiveness.

On the Anatomy of the Brain in some small Quadrupeds. *By* Robert Garner, *F.L.S.*

The comparative anatomy of the brain, little studied in Great Britain (Professor Owen having been one of the few labourers in the field), has on the continent met with more attention, witness the accurate researches of Tiedemann, Desmoulins, and Leuret. As the importance of the subject in regard to zoology and physiology cannot be doubted, the writer offers the description of the brain in a few small but interesting quadrupeds dissected by himself.

The two genera constituting the great family of quadrupeds, called Monotremata, similar in some respects, as far as the brain is concerned, are in others remarkably different. The *Echidna Histrix* has well-developed convolutions to its brain, that of the *Ornithorhynchus paradoxus* is only marked by the rather deep grooves of its vessels; it has, too, a bony lamina between the hemispheres, which is wanting in the other. The former has the olfactory bulbs very large, the latter much less. The *Echidna* has not the little side lobules of the cerebellum, which in the *Ornithorhynchus* are remarkable, occupying cavities in the temporal bone, and encircled by the three semicircular auditory canals; in the *Echidna* these last also exist, but deep in the solid bone. The *Ornithorhynchus* has the two posterior prominences of the corpora quadrigemina very little developed, less than in any other quadruped, if we are not mistaken, making therefore a gradation to their disposition in birds. Both have the peculiarity (general, it would appear, in the Marsupialia and Monotremata) of the absence of the corpus callosum. The two principal commissures are the anterior and the fornix, both well-developed, the latter being continuous behind with the hippocampus major; itself very large in such animals as have large olfactory bulbs and tracts, with which it is connected. The remaining parts do not much differ from other quadrupeds.

With respect to the organs of sense, and the cerebral nerves supplying them, we may commence (having already noticed that the olfactory organs are enormously developed in the *Echidna*) by observing that the eye of the aquatic species, the *Ornithorhynchus*, has a supplementary valvular lid, the lens also being more convex than in the *Echidna*. There is a lacrymal apparatus and duct in the usual place. The cerebral nerves generally are upon the normal plan, but the duck-billed creature has the fifth nerve very greatly developed to supply its curious mandible, which must possess extraordinary sensibility, though of a subdued kind, from its leathery covering; similar to that of a hand with fine touch enveloped in a closely-fitting glove. The large nasal branch of the first or ophthalmic division of this fifth nerve, running in a peculiar canal, and the second division, of course, supply the upper mandible, and the third the lower. Six fasciæ of nerves, generally very large, are distributed to the former, and four to the latter, on each side. The author is not sure whether mention is made in authors of the little saccular organs with papillæ, situated on the front of the palate, immediately under the nostrils, the latter situated, of course, above, on the upper surface of the bill. Home does mention four rudimentary anterior teeth in addition to those commonly enumerated. The origin of the great fifth nerve is evidently below the pons from the medulla oblongata. The external ear-canal is long and sinuous in the *Ornithorhynchus*, with a wider opening and more regularly curved in the *Echidna*. The drum of the ear looks downwards in this last, a little forwards and outwards in the first, and here too it is smaller and longer. In both, the membrane is stretched on a separate rim of bone like a tambourin. Home and Blainville give only two bones, but there is a loose quadrate bone attached to the malleus, and on which the trumpet-shaped stapes rests; this must be the incus. The malleus is large and connected with the bony circle, and also, as usual, with the membrane. In the *Echidna* the narrow Eustachian tube opens just within the posterior extremity of the nares, whence a bristle may be passed into the cavity of the tympanum. In the *Ornithorhynchus* it appears to be wider. In the Echidna the Vidian nerve, with another twig or two, is seen in the roof of the cavity, and may be traced to the portio dura; there is also a very distinct tensor tympani muscle. The cochlea only makes one imperfect turn in both animals, but the semicircular canals are completely formed. In the *Ornithorhynchus* one surrounds the opening of the side cavity in the cranium, and gives origin to one end of another which descends just outside the condyle, the third lying horizontally round the floor of the said cavity. In this animal there is one large opening for the passage of the eighth and ninth nerves, partly closed by a membrane and situated before the large occipital foramen; the *Echidna* has openings for them in the temporal bone.

Whilst the *Ornithorhynchus* is a sort of quadrupedic wingless duck, the *Echidna* is, as is well known, an ant-eater, having a very extensible tongue, without teeth, and its mouth situated at the end of a callous tubular muzzle. Of course, however, such a muzzle must present a great difference in its nerves. In this animal the nasal portion of the ophthalmic, for instance, is small (this nerve being scarcely related to the nose as an organ of smell), and the other branches of the fifth are also moderate in size. The two specimens of *Echidna* examined by the author had evidently been amongst the ants, and the friend who forwarded them observed that the animal's strength is enormous, that it burrowed in banks, and could roll itself up into a ball. How beautifully the *Ornithorhynchus* or *Platypus* is adapted to obtain its food, insects and mollusks found at the bottom of rivers, must strike any observer.

In three or four species of marsupial animals, *Phalangista* and *Petauri*, the brain was principally remarkable for the peculiarity mentioned above, the absence of the corpus callosum, the fornix taking its place somewhat, and having in front four prolongations, two going forwards above the anterior commissure, and two downwards behind it. The cerebrum in all was perfectly smooth, whilst the cerebellum in all the animals described in this paper is divided into lamellæ. There are moderate olfactory bulbs in front, the cerebellum has the "flocks" or small side lobules, the corpora quadrigemina are well-marked and their tubercles equal, a little exposed, and the hippocampus large. Indeed, with the exception of the peculiar absence of the corpus callosum, leaving the third ventricle exposed between the hemispheres, the brain in all these animals may well be compared to that of a hare or rabbit.

These remarks were closed with a few words on the encephalon of those curious animals the moles, two or three species of which have been examined, including the Condylura with a curious star-like snout, to supply which enigmatical part, the supermaxillary nerves are greatly developed. Generally there was no difference between the brains of foreign species and that of the common European species. This creature, admirably furnished with an acute organ of smell, and a very perfect internal ear (opening by a very wide orifice on the shoulder in the Condylura), has, as is well known, a very small rudimentary eye, a mere dot in fact. Nevertheless this eye has undoubtedly a true optic nerve, as was maintained by Treviranus and Carus; in fact, the figure given by the latter appears to me to be correct; at any rate, an optic nerve may be seen (by the lens) to whiten by the action of spirit, when examined at its commissure. The brain of this little creature, in some respects like that of the *Echidna*, has nevertheless a well-marked corpus callosum. The olfactory bulbs and tracts are ample, and connected through the hippocampus with the fornix, disposed as mentioned above. The anterior commissure is bifurcate on each side, with extensive connexions. The optic lobes, or corpora quadrigemina, are fairly developed, though the posterior one is certainly not so well marked; but still both are more so than could be the case if the sole relation of these parts were to the organs of vision, so rudimentary in the mole. The circle of Willis and other vessels are as regular and complicated as in the largest of the Mammalia.

On the Death of the Common Hive Bee, supposed to be occasioned by a Parasitic Fungus. By the Rev. H. H. Higgins.

On the 18th of March last a gentleman of Liverpool communicated to me some circumstances respecting the death of a hive of bees in his possession, which induced me to request from him a full statement of particulars. He gave me the following account:—"In October last I had three hives of bees, which I received into my house. The doorway of each hive was closed, and the hive was placed upon a piece of calico; the corners were brought over the top, leaving a loop, by which the hive was suspended from the ceiling. The hives were taken down about the 14th of March; two were healthy, but all the bees in the third were dead. There was a gallon of bees. The two hives containing live bees were much smaller; but in each there were dead ones. Under whatever circumstances you preserve bees through the winter, dead ones are found at the bottom of the hive in the spring. The room, an attic, was dry; and I had preserved the same hives in the same way during the winter of 1856. In what I may call the dead hive there was abundance of honey when it was opened; and it is clear that its inmates did not die from want. It is not a frequent occurrence for bees so to die; but I have known another instance. In that case the hive was left out in the ordinary way, and probably cold was the cause of death. I think it probable that my bees died about a month before the 14th of March, merely from the circumstance that some one remarked about that time that there was no noise in the hive. They might have died earlier, but there were certainly live bees in the hive in January. I understand there was an appearance of mould on some of the comb. There was, I think, ample ventilation; indeed, as the hives were suspended, they had more air than through the summer when placed on a stand. When the occurrence was first made known to me, I suggested that the bees might probably have died from the growth of a fungus, and requested some of the dead bees might be sent to me for examination. They were transmitted to me in a very dry state, and a careful inspection with a lens afforded no indication of vegetable growth. I then broke up a specimen and examined the portions with a compound microscope, using a Nachet, No. 4. The head and thorax were clean, but on a portion of the sternum were innumerable very minute linear slightly curved bodies, which, when immersed in water, showed the well-known oscillating or swarming motion. Notwithstanding the agreement of these minute bodies with the characters of the genus *Bacterium* of the Vibrionia, I regarded them as spermatia, having frequently seen others indistinguishable from them under circumstances inconsistent with the presence of confervæ, as in the immature peridia and sporangia of fungi. In the specimen first examined were no other indications of the growth of any parasite; but from the interior of the abdomen of another bee I obtained an abundance of well-defined globular bodies resembling the spores of a fungus, ·00012–·00016 inch in diameter. Three out of four specimens, subsequently examined, contained within the abdomen similar spores. No traces of mycelium were visible; the plants apparently had come to maturity and withered, leaving only the spores. The chief question then remaining to be solved was, as to the time when the spores were developed, whether before or after the death of the bees. In order, if possible, to determine this, I placed four of the dead bees in circumstances favourable for the germination of the spores, and in about ten days I submitted them again to examination. They were covered with mould consisting chiefly of a species of *Mucor*, and one also of Botrytis or Botryosporium. These fungi were clearly extraneous, covering indifferently all parts of the insects, and spreading on the wood on which they were lying. On the abdomen of all the specimens, and on the clypeus of one of them, grew a fungus wholly unlike the surrounding mould. It was white and very short, and apparently consisted wholly of spores arranged in a moniliform manner like the filaments of a penicillum. These spores resembled those first found in the abdomen of the bees, and did, I think, proceed from them. The filaments were most numerous at the junction of the segments of the abdomen. The spores did not resemble the globules in *Sporendonema muscæ*. The Rev. M. T. Berkeley, to whom I sent some of the bees, found, by scraping the interior of the abdomen with a lancet, very minute curved linear bodies which he compared to vibriones. He found mixed with them globular bodies, but no visible stratum of mould. From the peculiar position of the spores within the abdomen of the bees, and from the growth of a fungus from them unlike any of our common forms of Mucedines, I think it probable that the death of the bees was occasioned by the presence of a parasitic fungus."

On a New Species of Laomedea; *with Remarks on the Genera* Campanularia *and* Laomedea. *By the* Rev. T. Hincks, *B.A.*

A new British species of *Laomedea* was described under the name of *L. angulata*, which is remarkable as being the only member of this genus yet discovered, in which the reproductive capsules are not axillary, but originate from the creeping fibres. Mr. Hincks also described a remarkable variety of *Campanularia Johnstoni* (Alder), which is branched, and bears capsules on the pedicle as well as on the fibre. In these two forms, the supposed distinctive characters of *Laomedea* and *Campanularia* are intermingled. There was not, indeed, a single constant character that could be relied upon for the separation of the two genera, and he therefore proposed, with Van Beneden, to range both branched and simple forms under *Campanularia*, abandoning the genus *Laomedea*. One section, however, of *Campanularia* seemed to him entitled to distinct generic rank; that which includes the small and (for the most part) sessile species, and for this he proposed the name *Calicella*.

On three New Species of Sertularian Zoophytes. By Joshua Alder, *of Newcastle-on-Tyne. Communicated by the* Rev. Thomas Hincks.

The first was a *Plumularia* of well-marked characters, discovered by Mr. Alder, near low-water mark, at Cullercoats, on the Northumberland coast: in habit it very much resembled a *Halecium*, but with ovicapsules similar to those of *Campanularia Johnstoni*. It was named *Plumularia halecioides*. The second species described was a *Halecium* from deep water on the same coast, for which the name of *H. labrosum* was proposed. The third, a foreign species, was found parasitic on gulf-weed from the Atlantic, and was named *Halecium nanum*. The paper was illustrated by drawings of the several species.

On the Homology of the Skeleton.
By G. M. Humphry, *Surgeon to Addenbrooke's Hospital, Cambridge.*

Having lately been engaged in lecturing and writing upon the Human Skeleton, the author has carefully investigated the whole subject of its homology, in relation to the skeletons of the various vertebrate classes, and in relation to its development and connexion with the nervous system. The conclusions at which he arrives differ, in some particulars, from those of Prof. Owen, more especially with regard to certain bones of the skull, such as the temporal bone, and the components of the anterior or nasal vertebra. His views, and the arrangement he proposes, are set forth in the accompanying Table I. In Table II. the bones are placed according to the plan of Prof. Owen; the differences between the two being indicated by italics. He considers that the pelvis consists of the hæmal elements of two sacral vertebræ; that the scapular arch consists of the hæmal elements of two cervical vertebræ; and that the limbs are appendages diverging from the points of junction of the hæmal spines with the hæmal alæ. The key to the comparison of the fore limbs with the hinder—a subject of much difficulty to anatomists—is furnished by the fact that the limbs are placed at the anterior and posterior ends of the trunk; and that consequently the opposed surfaces of their upper segments, as well as of the pelvis and scapula, are made to correspond; that is, the anterior aspect of the hinder limb corresponds with the posterior aspect of the fore limb. This disposition of the parts takes place during development. At first, each limb is nearly straight; the hands and feet bud out from the sides of the trunk; the palms and soles look downwards; and the thumb and the great toe look forward. Subsequently, each limb undergoes a quarter turn, but in opposite directions. The anterior limb is rotated, on its axis, backwards; the posterior limb is rotated, on its axis, forwards; the ilium and femur slant, forwards, from the hip; and the scapula and humerus slant, backwards, from the shoulder; the knee bends forwards; and the elbow bends backwards. In the anterior limb, however, a rotation of the distal segments takes place, when the hand is pronated, in an opposite direction to that which has occurred in the proximal segments; and pronation is the easiest position to man, and is the ordinary position with most other animals.

Sense-Bones and Cartilages.	Auditory. Tympanic and petrous parts of temporal.		Auditory. Ossicula auditus.	Auditory. External cartilages.		Optic. Tarsal cartilages.		Turbinate bones.		Nasal. Cartilage of septum.	External cartilages.	
Cranial Vertebræ arranged homologically.												
	Central parts.			Neural.			Transverse.			Hæmal.		
Vertebræ.........	Central.	Supra-Central.	Infra-Central.	Ala.	Spine.	Articulating processes.	Process. Superior.	Process. Inferior.	Ala.	Ala.	Spine.	Diverging appendage.
1. Occipital	Basilar part.		Pharyngeal tubercle.	Side of foramen magnum.	Expanded part of occipital.	Condyles.	Jugular process.		Mastoid.	Lesser cornu of hyoid.	Body of hyoid.	Great cornu of hyoid.
2. Post-sphenoid..	Post-sphenoid body.	Posterior clinoid. Hinder part of olivary tubercle.	Hinder part of Rostrum.	Great ala of sphenoid.	Parietal.		External pterygoid.	Internal pterygoid.	Squamous.	Condyle of lower jaw.	Ramus of lower jaw.	Angle of lower jaw.
3. Pre-sphenoid ..	Pre-sphenoid body.	Fore part of olivary tubercle.	Fore part of rostrum.	Small ala of sphenoid.	Frontal.		Laminæ on sides of sphenoid sinus.		Palate.	Superior maxilla.		Malar and Lacrymal.
4. Ethmoid........	Median plate of ethmoid.	Crista Galli.	Vomer.	Cribriform plate of ethmoid.	Nasal.		Lateral portion of ethmoid.			Intermaxillary bone.		

Table II.

	Centrum.			Neurapophysis.	Neural spines.	Zygapophysis.	Diapophysis.	Parapophysis.	Pleurapophysis.	Hæmapophysis.	Hæmal spine.	Diverging appendage.
1. Occipital	Basilar part.			Side of foramen magnum.	Expanded part of occipital.	Condyle.		Jugular process.	*Scapula.*	*Coracoid.*	*Episternum.*	*Fore limb.*
2. Parietal	Post-sphenoid body.			Great ala of sphenoid.	Parietal.			*Mastoid.*	*Styloid.*	*Lesser cornu of hyoid.*	*Body of hyoid.*	*Great cornu of hyoid.*
3. Frontal..........	Pre-sphenoid body.			Small ala of sphenoid.	Frontal.			*External angular process of frontal.*	*Tympanic.*	*Condyle of lower jaw.*	*Ramus of lower jaw.*	*Malar and Squamous and Pterygoid.*
4. Nasal............	*Vomer.*			*Median and cribriform plates of ethmoid.*	Nasal.				*Palate.*	*Superior maxillary.*	*Inter-maxillary.*	

On the Liability of Shells to Injury from the Growth of a Fungus. *By the* Rev. H. H. Higgins.

It has often been observed that shells kept for a considerable time in cabinets are apt to lose much of their original freshness and beauty of appearance. This kind of injury chiefly affects such specimens as have a bright enamelled surface, which at length becomes dull and less pleasant to the touch. Several suggestions have been made with reference to the probable cause of the change, which has often been attributed to the efflorescence of saline matter absorbed by the shell. But, so far as I have observed, the specimens most liable to injury from saline incrustation belong to genera in which the shells are without enamel, as *Littorina*, *Turritella*, &c., and many collectors are in the habit of steeping their specimens in fresh water for some days before placing them in their cabinets—a process which is said to be an effectual preservative from injury by saline efflorescence. Mr. Dennison, of Woolton, attributed the loss of lustre in enamelled shells to the ravages of a minute insect, but had not been able to detect the depredator. "Many of the shells in my own cabinet suffered such serious injury during last winter that I was led to investigate the cause, which, indeed, became obvious enough by the use of a microscope. An ordinary lens showed the enamel of the shell to be beset with small bristly points, and when a portion of the surface was scraped off and submitted to a higher magnifying power, the forms of at least two species of Fungi became apparent, one resembling an ordinary Mucor with a globose sporangium; the other, and much more common form, exhibited both simple and moniliform filaments, with an abundance of minute spores, seemingly quite free. After having been carefully washed, the surface of the shell was found to be as if it were engraved in some places with stellular marks, in others with striæ forming irregular reticulations, caused no doubt in each instance by the spreading mycelium of the fungus. It is scarcely necessary to add, that attacks of this nature need not be apprehended where shells are kept in a perfectly dry or well-ventilated place. A slight deposition of moisture does, however, frequently occur upon their surfaces whilst shells are undergoing examination, in which case it would be a safe precaution to allow them for awhile to remain exposed to the air before returning the drawer to the cabinet."

On some new and interesting Forms of British Zoophytes. *By the* Rev. T. Hincks, *B.A.*

A new species of *Plumularia* was characterized under the name of *P. similis*, closely allied to the *P. echinulata* of Peach. Two new species of Polyzoa were also described: one as *Avenella dilatata*; the other, which exhibits a new generic type, as *Arachnidia Hippothöoides*, a delicate Ctenostomatous Polyzoon, curiously resembling in general appearance the well-known *Hippothoa*. Mr. Hincks also drew attention to the remarkable difference in the form of the male and female capsule in *Halecium Beanii* and *H. halecinum*, and suggested the importance of inquiring how far this difference prevails amongst true *Hydroida*.

On some Peculiar Forms of Spines found on two Species of the Spinigrade Starfishes. *By* C. W. Peach.

The author stated, that having discovered a long slit on the under spines of *Ophiocoma neglecta*?, he was induced to examine other species; and that on *Ophiocoma rosula*, in addition to those mentioned by Forbes, he found jaw-like ones on the under sides of the rays, armed with hooked teeth—much like one of the claws of a lobster—and likewise a hook on the tips of the lower straight spines, all directed towards the disk. Similar jaw-like spines occur on the arm of an *Ophiocoma minuta* sent by Dr. Dickie from the collection of the late Mr. Thompson of Belfast; and as the author found several specimens, in all stages of growth, at Wick, N. B., in every respect like the Irish one, he thinks that the latter is only the young of the former. From not finding these noticed by Forbes, or any other writer on Starfishes, he has thought it right to lay this before the Association.

Notice of a number of Earth-worms and Larvæ of an undescribed Species found in draining a field upon his Estate. By Henry Peckitt.

These worms were exhibited with a view to ascertain whether they were really foreign worms, or the common worms rendered energetic from some particular state of the soil. The working of the worm was first noticed about sixty years since on the site of a stick or rubbish heap at the Old Hall of Thirkleby Park; it has now spread over the gardens and park, and covers a surface of 200 acres. The casts are so large and numerous as to render the eatage impracticable within 4 inches of the ground. The workings are seen again at Baldersby Park, a distance of 8 miles, the Swale intervening. About five years since a small beginning was discovered in a field 3 miles from Thirkleby, which has now spread to an acre. The worms are subsoiling the land, and the land is enriching from the great quantity of grass yearly (wasted to the occupier) trodden down uneaten. From the site on which they first appeared, it has been suggested that it may have been an imported worm thrown from some garden pot.

It was also supposed that the destruction of the rooks at one time at the park allowed the worms to get a-head, but it is doubtful whether rooks take a worm when other food is to be had. The field has a Rookery at the end of it. In collecting worms for the Meeting, it was noticed that the rooks had torn up the grass in various parts of the field, and on examination it was found they were after the larvæ, which were exhibited. This field was drained two years since 4 feet 6 inches deep as a check upon the worm, but no effect is yet observable.

Notes on Myrmecophilous Coleoptera. By Dr. J. A. Power.

I imagine that the interest of the entomologists of the Association may possibly be excited by a tolerably complete collection of the known British Myrmecophilous insects. It is a group which until recently has been almost unknown to our naturalists, and embraces a considerable number of creatures which had hitherto escaped their researches. Most of these singular animals appear to spend their lives, sometimes in the immediate vicinity of the ants' nests, sometimes in the very heart of them; and although endowed with ample powers of flight, wander but little from their quarters. Hence it has happened, that only a casual specimen has now and then fallen to the lot of the collector, whilst the greater part have been unknown, or known only as unique, or nearly unique examples, and even their authenticity suspected. Messrs. Janson and Waterhouse acting as pioneers, Messrs. Reading, Edwin Sheppard, Douglas, myself, and sundry others, have, within the last few years, by carrying on the war in and about the nests themselves, brought to light many new species, or found others to be abundant which were previously almost unknown. Mr. Janson has, in the 'Entomologist's Annual' of last year, published a most valuable account of the habits of these insects, and the mode of searching for them. I must say, however, that I cannot sympathize with him in his tender feelings towards these voracious hosts of our coleopterous favourites. According to my own experience, the spring, *i. e.* about April and May, is the most productive season for examining the nests of *Formica rufa* (which affords much the greatest number of insects), before the ants have actively begun their labours: the Coleoptera then seem to be accumulated in their immediate neighbourhood, instead of being scattered over a large extent of ground as they subsequently are. Soon after this period we often see the ants commence the process of gradually deserting an old and inconvenient nest, and taking up new quarters close by. I have found these old nests afford by far the best harvest of insects, which in the appetite for formic acid or its odour, (apparently necessary to their constitution), congregate amongst the few remaining ants. If a few showers of rain should then fall and wash away the acid, the beetles entirely desert the nest. The most efficient plan of search with this nest, is to place a few handfulls of the material taken from near the ants, upon a somewhat fine cabbage-net, laid on a sheet of brown paper. Saprini, Dendrophili, &c. have a tendency, when disturbed, to make their way downwards, and if, after a short time, you lift the net to another part of the paper, you remove the *débris*, and leave the insects behind. The outskirts of the nests should also be well examined, as Mr. Janson describes, looking under stones, &c. The nests of *Formica fuliginosa* are more productive rather later, when the ants are in activity; but the investigation is to be carried on chiefly in the *neighbourhood* of the nest, in damp places around it, and where the ants run. The ground being stirred up, the insects will appear if you watch for them. Little is usually to be obtained *in* the nest, which is generally in the trunk of an old tree. The nests of *F. fusca*, *F. flava*, and *Myrmica rubra* afford but few species, and these are chiefly to be found in the galleries, under stones, &c. which may lie upon the nests. It is reasonable to expect that more species may be obtained by the examination of the nests of other ants, especially as the denizens of one kind appear seldom to associate with those of others. *Formica fusca* and *F. flava* seem to be the most convertible, *i. e.* you often find the same insects in both. In the nests of *F. fuliginosa* you almost invariably find something. As to those of *F. rufa*, you get many in some, but in very many nothing. Of those of *F. flava*, *F. fusca*, and *Myrmica rubra*, you may examine hundreds and get nothing. As yet we have obtained results from only a few species, viz. *Formica sanguinolenta*, *F. flava*, *F. fusca*, *F. fuliginosa*, *F. rufa*, and *Myrmica rubra*. The author illustrated his paper by specimens of the ants, and under each placed the genera and species of Coleoptera usually associated with them, and which may be expected to be found in their nests. He also subjoined to the Catalogue remarks on the localities and habits of the individual species.

On the Occurrence of Bombyx mori *in a wild state in this Country. By the* Rev. F. F. Statham, *Incumbent of St. Peter's, Walworth.*

The author referred to the many costly attempts which have been made during the last two centuries to domesticate the *Bombyx mori*, or common silkworm, in this country, all of which had proved unsuccessful hitherto from the rigour of the climate and other causes. He then instanced the following curious fact, as an illustration of the power of instinct in enabling the insect to adapt itself to circumstances, and argued the possibility of rearing a more hardy species of *Bombyx*, which might hereafter be made useful for commercial purposes, giving, as his authority for the statements, the Rev. W. Fox, curate of West Malling, Kent, to whom he had been indebted for them. On the 10th of July, in the present year, a number of silkworms, estimated at from 80 to 100, were found under a hedge in a place called Banksfield, near West Malling, not far from Maidstone, Kent. There was no appearance of the insects having been scattered accidentally in the place; but, on the contrary, every indication of their having been hatched and sustained for some time in the spot where they were discovered. The leaves of several plants in the immediate vicinity were much jagged and eaten, showing plainly that the insects had for some time been feeding upon them. A bush of the *Rubus fruticosus*, the common bramble, among others, had been partially despoiled of its leaves. When discovered, about three-fourths of the whole number had spun their cocoons, which were hanging in all directions upon the weeds and the bramble referred to. Some were just commencing the spinning process, while others were yet in the larva state, and were feeding quietly or roving about in quest of suitable places in which to construct their silken cells. Both the silk cocoons and the remaining larvæ were subjected to a close examination by the aid of a microscope, and were compared with other silkworms and cocoons, which had been bred or formed under the shelter of a house, but no perceptible difference of species could be discovered by those who conducted the examination. The reverend gentleman expressed his dissent from the opinion which prevailed in the neighbourhood of the occurrence, that the insects had been the produce of a moth which might have fluttered away from the town during the preceding summer, and accounted for their appearance by imagining that some piece of paper having the ova deposited on it had been blown from a window-sill or other lofty spot, where it had been exposed to the rays of the sun, and had gradually been swept by currents of wind into the locality where the insects were found, where, having been favourably settled as regards warmth and shelter, the young larvæ had emerged from their eggs, and sought congenial nourishment amidst the surrounding vegetation. The author alluded to the recent failure in the breed of silkworms in France, as announced in the *Times* of the 9th of September, and argued the utility of trying a series of experiments to ascertain whether (as apparently indicated by the Town Malling discovery) the *Bombyx mori* could not be reared upon plants of indigenous growth, and without that amount of care and expense which have hitherto been considered indispensable.

On the British Wild Geese. *By* A. Strickland.

Geese are a natural group of birds possessing several strongly marked characters; some of them are so alike in plumage that that important character can hardly be taken as an element to assist in discriminating the species; the form and colour of their bills and legs, and the habits of the birds in a state of nature being all we can safely rely upon: besides this, from their shy nature, they are the most difficult birds to study; from these circumstances the authors of British Birds seem not to have duly examined the characters of the species they describe. Mr. Gould has given us but three species of British Wild Geese, confusing two species under the mysterious name of *Segetum*, or Bean Goose.

Anas albifrons, White-fronted Goose.—The plumage will mark this species; it is not, or probably never was, a regular migratory species in this country, but is found in hard weather frequenting running streams and swampy ground singly, or in small groups; but is stated to be found in large migratory flocks on the continents of Europe and America.

Anas ferus or *Anser*, never was a migratory species in this country, but permanently resided and bred in the Carrs of Yorkshire, and probably the fens of Lincolnshire; but it has long since been banished from these places, but still breeds sparingly in the Western Islands of Scotland. This bird displays the same delicate pink colour in its bill when young, as the Bean Goose does in its legs, and which has eroneously been considered a distinct species, under the name of Pink-footed Goose.

From time immemorial one of the features of the north and east of England has been the regular periodical appearance of countless flocks of wild geese which arrive about the end of harvest, and which received the name of Bean Goose as coming in the time of bean harvest, and when the bean stubbles were ready for them. *This species is the only one that has any claims to the name of Bean Goose (or* Segetum), *the only migratory species in this country, and the only abundant and common species we have.* Unaccountable as the case may appear, this bird is not figured or characterized in any workol Natural History I am acquainted with, and is not mentioned in the works of Mr. Yarrell, Mr. Gould, or Morris, further than ascribing the habits of this bird to one given by these authors under the figure and description of an entire different species under the erroneous name of *Segetum*, or Bean Goose. Some years ago, Mr. Bartlet, struck with the difference between the geese he met with in the market and the descriptions and drawings given of the Bean Goose, was induced to constitute a new species under the name of Pink-footed Goose; but this was an erroneous view of the matter, being in fact the young or immature bird of the true Bean Goose. This bird, the true *Segetum*, or Bean Goose, or Short-billed Goose, is distinguished by its short and strong bill, its depth at the base being nearly two-thirds of its length, and by its migratory habits differing in that respect from all our other geese arriving every autumn, spreading during the day time over the stubbles and clover fields on the Wolds and other open districts, rising like clock-work in the evening, and winging its way in long strings to the sand-bank in the Humber, and other safe retreats for the night, returning as punctually in the morning to its feeding-grounds. This bird differs from the Pink-footed Goose in being larger, having a stronger bill and lighter plumage; but these differences are the result of age, not of species, and due examination will confirm this. The next bird to be considered is the Long-billed Goose, figured and described by Mr. Yarrell, Mr. Gould, and Mr. Morris under the name of *Segetum*, or Bean Goose. This is distinguished by having the bill exactly twice the length of the depth at the base, a proportion quite different from the Short-billed Goose. Before the beginning of this century, when the Carrs of Yorkshire were the resort of countless numbers of wild-fowl, it was stated that there were two species of geese frequenting and breeding in the Carrs, known to the fowlers by the name of the Carr Lag and the Grey Lag. What the Grey Lag was is well known. The

Carr Lag is not now easy to identify, but the author thinks it was this Long-billed Goose, a bird that resided and bred in the Carrs along with the Grey Lag, and like that bird is no longer to be found in these districts, and is now one of our scarcest British birds, or almost a lost species. This bird is distinguished from the Bean Goose by its long bill, and its entirely different habits.

The following is a list of the species:—

Anas albifrons, White-fronted Goose.—Face white, bill flesh-coloured (Gould, No. 349); an occasional winter visitor in this country in small groups.

Anas ferus, or *Anser*, Grey Lag Wild Goose.—Breeds sparingly in this country, and is not a migratory species. Bill pink, nail white.

Anas Segetum, Bean Goose, Short billed or Migratory Goose.—Bill short, strong, the depth at the base being nearly two-thirds that of the length, pale red in the middle, black at the extremities, but varies much in the proportions of these colours. Old birds as large and pale coloured as a Grey Lag Goose. Pink-footed Goose, smaller bird, less and darker; the young of the last.

Anas paludosus, Carr Lag, or Long-billed Goose.—Bill long and weak, being exactly twice the length of the depth at the base, being $2\frac{3}{4}$ in. long and $1\frac{3}{8}$ in. deep at the base. Bill strongly toothed, a groove running the length of the lower mandible; colour same as last. Gould, plate 348, but not the description: not a migratory species.

On the Formation of the Cells of Bees. By W. B. Tegetmeier.

Having recently been engaged in making a series of experiments with a view to determine the typical form of the cells of bees, and having arrived at some interesting results, I am desirous of bringing them before the members of the British Association. My first experiment consisted in placing a flat parallel-sided block of wax in a hive containing a recent swarm. In this, cells were excavated by the bees at irregular distances. In every case where the excavation was isolated it was *hemispherical*, and the wax excavated was added at the margin so as to constitute a *cylindrical* cell. As other excavations were made in contact with those previously formed, the cells became flat-sided, but from the irregularity of their arrangement not necessarily hexagonal. When the block was coloured with vermilion, the employment of the excavated wax in the formation of the sides of the cells was rendered more evident. The experiment has been repeated with various modifications as to the size and form of the block of wax, but always with the same results,—namely, that the excavations were in all cases hemispherical,—that the wax excavated was always used to raise the walls of the cells, and that the cells themselves, before others were formed in contact with them, were always cylindrical. Mr. Charles Darwin, to whom I communicated these facts, has repeated the experiments with similar results. When these experiments are taken into consideration, in connexion with the facts that in the commencement of a comb the rudiments of the first-formed cells are always hemispherical, and that in a small extending comb the outer sides of the bases of the external cells are always circular, they appear to lead to the conclusion, that the typical form of a single cell is cylindrical, with a hemispherical base; but that, when the cells are raised up in contact with one another, they necessarily become polygonal, and if regularly built, hexagonal. On this supposition alone can those numerous cases be accounted for in which one side of a cell is cylindrical, the other polygonal. In all such cases it will be found that, in the cell adjacent to the cylindrical side, there is not room (owing to some irregularity of the comb) for a bee to work,—consequently the cylindrical development is not interfered with. The formation of the small cylindrical cells surrounding the queen cell appear to admit of no other explanation. The mode in which the circular bases, situated at the thin edge of a comb in the process of enlargement, become converted into polygonal cells as new bases are formed on their outer sides, has been beautifully shown by Mr. Darwin. In repeating, with many ingenious modifications, my original experiments, he coloured, with vermilion and wax, the circular edges of the bases of the external cells in a small comb. On replacing this in the hive, he found that the walls of the cells were not raised directly upon these circular bases, but that, as other cells were built external to them, the coloured wax was remasticated and worked up into the polygonal sides of the cells; consequently the colour, instead of remaining as a narrow line, became diffused over a considerable portion of the sides of the cells. These observations have been much facilitated by the employment of a hive having each side formed of four parallel plates of glass, with thin strata of air between. As thus formed, the escape of heat is so effectually prevented that the bees work without the necessity of covering the hive with any opaque material, and thus they are always open to observation without being disturbed by the sudden admission of light into a hive previously dark. Crude and imperfect as these experiments may be, they appear to me to have an important bearing on the theory of the formation of cells, and my desire that they may be repeated and extended by other observers must plead my excuse for bringing them before the notice of the Association.

On Aquaria. *By* N. B. Ward, *F.R.S.*

The author proceeded to consider the application of those principles which had proved so successful with plants to the subjects of the animal kingdom. At the meeting of the British Association at Liverpool in 1838, he directed the attention of the members to the extension of his principle to animals. He felt quite certain that a great number of animals would live and thrive under the same treatment, and he could see no reason why, at the same time that our stoves were ornamented with Rafflesias, they might not be illuminated with Fulgoras and Candelarias. In the same year he addressed a letter to Sir W. Hooker, in which he expressed his belief that animals as well as plants might be imported in the case, and these views were stated by Prof. Faraday at the Royal Institution. In 1841 he established the first aquarium for fish and plants in his fern-house in Wellclose Square, his object being *not* to determine the counterbalancing influence of plants and animals in water,—that having been ascertained long before by Priestley;—but to determine whether the limited quantity of air in the fern-house would be sufficient for the well-being of the fish. This plan was shortly followed by Dr. Bowerbank in a large glass jar, which, when seen by Mr. Mitchell, occasioned the construction of the Vivaria in the Regent's Park.

Mr. Ward read a communication from Mr. Mummery, detailing his experiments on marine animals and plants during his residence at Dover, illustrated by some very beautiful representations of some of the animals which were living in his aquarium. Of the permanent inhabitants were the following:—*Actinia crassicornis, A. gemmaria, A. anguicoma, A. Dianthus, A. miniata, A. bellis, A. nivea, A. mesembryanthemum, Sertularia planula, Bowerbankia densa, Pedicellina belgica, Tubularia indivisa* (in various states), *Aphrodite aculeata, Serpula contortuplicata, Pagurus Bernhardi, Portunus puber, Balanus balanoides, Buccinum undatum, Patella, Æolis lineata, Palæmon.* The three following could only be kept for a very few days: *Lepas anatifer, Cydippe pileus, Lucernaria auricula.*

Mr. Ward gave a glowing description of the coral reefs of Rottenset Island, Western Australia, by Dr. Harvey, of Dublin, and strongly advocated the importation from thence of some of the beautiful forms of vegetable life, such as *Caulerpa, Bryopsis,* &c.

The paper was illustrated by a collection of cultivable sea-weeds from the herbarium of Dr. Harvey, of Cork, and a series of coloured diagrams of animals inhabiting aquaria, by Mrs. Mummery.

On the Multiplication of Actiniæ in Aquaria. *By* R. Warington, *F.C.S.*

The author described the several processes of reproduction occurring amongst these creatures: the first, in which a portion of the base or foot becoming separated from the Actinia, split up into three or four portions, each giving rise to a new Actinia; the second, in which the body of Actinia was fissured or divided into two distinct individuals; and the third, when the perfect young are developed from the mouth. The author called the attention of Naturalists to these points as being of use in classifying the species, and gave the names of the many varieties in each of these sections which had come under his notice since 1851.

Physiology.

On some Observations connected with the Anatomy and Functions of the third, sixth, and seventh pairs of Nerves and the Medulla oblongata. By Dr. Achille Foulle.

On the Sensational, Emotional, Intellectual, and Instinctive Capacities of the Lower Animals compared with those of Man. By Richard Fowler, *M.D., of Salisbury.*

The author submitted that the Deity had formed all animals, both mentally and corporeally, on one type. All had like sensations. All vertebrated animals had like conceptions of persons and of places; the constituents of memory, like the re-transmissions from conceptions to adjusting muscles of the functions of actions, as might be observed by the barking of dogs and their efforts to run in their sleep. They had like memory of persons and things; like powers of comparing those with their conceptions after long absence; and like volition for the gratification of their appetites. But they had not, as man had, such perception of objects and their relations as enabled them to form new combinations, and thus to be the source, by a sort of creative power, of new ideas. There was no instance of a physical force having been used instrumentally by any of the lower animals. No monkeys, however often they might have seen a fire lighted and been comforted by its warmth, had ever been known to light a fire. They appeared to have like conceptions of objects, but not of their qualities or relations to each other. The instinctive functions seemed to be actuated by the forces of mind and vitality, by appropriate and limited structures, with adjustible muscles analogous to the different organs of sense; and this instinctive apparatus, with like analogy to the organs of sense, had affinity for the objects.

The lower animals had one decided advantage over man in an uneducated state—their comfort was not disturbed by false notions of religion. Man was the highest being to whom the thoughts of animals were directed, and their attachments to him appeared quite as strong as those of men to each other. Animals had equal attachments to home, and the nostalgia which a continued absence inflicts was perhaps as painful as any that men suffer.

Evils were common both to men and animals. The greater part of the evils inflicted on men proceeded from their own misconduct. But there were other evils evidently intended to impel us to cultivate our intellect and our talents by searching for the means to remove them. Thus the scurvy was an evil, and our search had removed it by lemon-juice; malaria was removeable by ventilation and drainage; distance of time and space science had removed by our railways and telegraphs; the dangers of navigation had been reduced by harbours of refuge, recent observation of currents, and the rotations of storm; small-pox had been antagonized by vaccination, pain by chloroform; famine, the herald of pestilence, had been prevented by agricultural improvements; might it not be hoped that the mind would be equally successful in diminishing the remainder of our evils? Ignorance was perhaps our greatest evil, the source of so many others; crime the greatest of all, by the misery which it inflicted. But how, as to the evils to which animals were liable, without the mental means of subverting them? To man this life might perhaps be considered as a school of conduct, in which evils were our schoolmasters to urge us to "seek that we may find;" to "knock that it may be opened unto us." Even our mental evils were lessons, when they were antagonized by thoughts and actions that tended to the comfort of others, or the progressive advancement of our own minds. Was not that a proof of the benevolence of the moral law by which we were governed? But animals had no such resource. Was not that an argument which should induce man to act towards them as the Governor of the Universe deals with man?

No animal inferior to man has ever been known to create a work of art, discover a law of nature, and comprehend or apply it when produced by man. But man creates works of art, discovers laws of nature, and applies them to advance his rank in the scale of being. It may be therefore true of animals, that nothing enters the intellect but the single objects which pass through their senses without perception of the relations which they bear to each other; but it is not true of man, who does create new phenomena.

Notes of Experiments on Digestion. *By* G. Harley, *M.D., F.C.S., F.R.C.P.E.*

The communication was illustrated by numerous experiments showing the properties of the saliva, the gastric juice, the bile, and the pancreatic secretion.

The author stated that, contrary to an opinion lately published by Bernard, the distinguished French physiologist, he had found that the human saliva contains both sulphocyanide of potassium and iron. The latter substance, however, can only be detected after the organic matters contained in the secretion are destroyed by burning. He had ascertained that a person of nine stone secreted between one and two pounds of saliva in twenty-four hours. 100 parts of mixed saliva yielded on analysis,—

Water		99·331
Solids		0·669
Ferment, Albumen, Caseine, Mucus and epithelium	organic matter	0·391
Chloride of sodium, Sulphate of potash, Sulphocyanide of potassium, Phosphate of lime, „ magnesia, and iron	inorganic matter	0·278

The gastric juice, the author said, does not destroy the power possessed by the saliva of transforming starch into sugar; consequently the digestion of amylaceous food is continued in the stomach. The gastric juice has the property of changing cane- into grape-sugar. 100 parts of pure filtered gastric juice, obtained through a fistulous opening in a dog's stomach, yielded on analysis,—

Water		97·288
Solids		2·712
Organic matter, chiefly pepsin		2·247
Chloride of sodium, „ potassium, Phosphate of lime, „ magnesia, and iron	inorganic matter	2·247

The author made some remarks upon the cause of the gastric juice not digesting the living stomach; and said that his experiments showed that it is not so much the epithelium lining the organ which prevented its being digested, as the layer of thick mucus which covered its walls. When the latter substance is absent, the gastric juice attacks the walls of the living stomach and digests them, causing perforation and death. As regards the bile, it seems that this secretion takes an active part in rendering the fatty matters of our food capable of being absorbed into the system. The most curious of all the digestive fluids, however, is the pancreatic secretion, for it appears to unite in itself the properties of all the others. It not only transforms starch and other such substances into sugar, but it emulsions fats, and even to a limited extent, as first pointed out by Pappenheim and Purkinje, digests proteine compounds.

The Spinal Chord a Sensational and Volitional Centre. *By* G. H. Lewes.

The spinal chord, the author stated, was formerly believed to be nothing but a great nerve-trunk; and even now its functions have been limited to the transmission and reflexion of impressions. That it can conduct impressions to the sensorium and reflect them on the motor nerves, producing muscular contraction, is all that physiologists are willing to allow. Doubts having long rested on his mind upon this point, the author had made a series of experiments, which, together with those of Pflüger, had led him to a clear conviction.

Before detailing the evidence for the sensorial functions of the chord, it will be necessary to fix on some broad and palpable signs, such as unequivocally indicate the presence of volition. We have such signs in spontaneity of actions and choice of actions. It will scarcely be disputed that an animal manifests volition—and its act is voluntary—when the act occurs spontaneously. By "spontaneously," I mean prompted by some inward impulse, and not excited by an outward stimulus. Spontaneity and choice are two palpable characteristics of sensation and volition, and it is these we must seek in our experiments. Those who for the first time perform, or witness, experiments on decapitated animals, find it very difficult to believe that these animals have no sensation; but their doubts are generally settled by a reference to the admitted hypothesis of the brain being the exclusive seat of consciousness. On the strength of this hypothesis, the striking facts recorded by Legallois, Prochaska, Volkmann, and others, have been explained as simple cases of the reflex action of the chord. Against this hypothesis of the brain being the exclusive seat of consciousness, I have for some years gathered increasing strength of conviction, preferring the hypothesis of the sensorium being *co-extensive with the whole of the nervous centres*. From the mass of evidence furnished by experiments, all bearing on the same point, the sensational function of the chord acquires in my mind the force almost of a demonstrated truth. From that mass a few cardinal cases may be selected. If they do not carry conviction, there can be little hope in any accumulation of such cases.

Place a child of two or three years old on his back, and tickle his right cheek with a feather, he will probably first move his head aside, and then, on the tickling being continued, he will raise his right hand, push away the feather, and rub the tickled spot. So long as his right hand remains free he will never use the left hand when the right cheek is tickled, or *vice versâ*. But if you hold his right hand, he will rub with the left. The voluntary character of these actions is indisputable, in spite of their uniformity; they are prompted by sensation, and determined by volition.

Let us now contrast the actions of the sleeping child under similar circumstances, and we shall find them to be precisely similar. "Children," says Pflüger, "sleep more soundly than adults, and seem to be more sensitive in sleep. I tickled the right nostril of a three-year old boy. He at once raised his right hand to push me away, and then rubbed the place. When I tickled his left nostril he raised the left hand. I then softly drew both arms down, and laid them close to the body, imbedding the left arm in the clothes, and placing on it a pillow, by gentle pressure on which I could keep the arm down without awakening him. Having done this I tickled his left nostril. He at once began to move the imprisoned arm, but could not reach his face with it, because I held it firmly though gently down. He now drew his head aside, and I continued tickling, whereupon he raised the right hand, and with it rubbed the left nostril, an action he never performed when the left hand was free."

This simple and ingenious experiment of Pflüger establishes one important point, namely, that the so-called reflex actions in sleep are not unaccompanied by sensation and volition. The sleeping child behaves precisely as the waking child behaves, except that his actions are less energetic; and we are forced to assume the presence of dim cerebral consciousness to escape the conclusion that the spinal chord is also a seat of consciousness. The actions of the sleeping and the waking child are so similar, that both must be credited with sensation and volition (and if not both, then neither must be so credited); in like manner I shall show that the actions of animals before and after decapitation exhibit no more difference, as respects sensibility, than the actions of the waking and the sleeping child; so that here again, unless both actions are credited with sensation and volition, neither of them can put in a claim.

Experiment leads decisively to this alternative, namely, either animals are unconscious machines, or decapitated animals manifest sensibility and will. [Having detailed a series of experiments with a water newt, to show that the animal's actions were precisely the same before and after decapitation, and arguing that they displayed spontaneity of action—the paper proceeded.]—After allowing a quarter of an hour to elapse, in order to a more complete reinstatement of vigour, I touched the flank as before, with acetic acid. The movements at first were very disorderly;

The animal ran about in great uneasiness, just as it had done before its head was off. In vain I waited for it to rub itself against the side of the box; it curled itself up, and seemed about to die. Some time afterwards I again touched it with the acid; it again became disorderly, and I then pushed it towards the side of the box; but it did not move until I pushed it slowly forwards so that its flank might come in contact with the wood; this succeeded: this seemed to supply the very remedy it wanted, for it continued crawling slowly and with intervals of rest, its body curved outwards so as to continue in contact with the wood, and its hind leg pressed close to the tail, and thus, as before, it rubbed away the acid. There are two points noticeable here:—first, the readiness with which a sensation of contact suggested a means of relief; secondly, that this was the only newt which, in my experiments, ever hit upon this plan, and this one did so as well without its head as with it. The repetition of the act precludes the idea of its being an accident.

It is unnecessary to trespass on your time by citing the observations of numerous physiologists testifying to the spontaneity of decapitated animals—all remember such cases. I divided the chord of a newt between the fifth and sixth cervical vertebræ. The convulsions which followed were almost as severe as those which follow decapitation. After a few minutes it tried to rise, but failed. Bubbles of carbonic acid were constantly expired. After fifteen minutes it turned completely round, and crawled five steps forward, dragging the hinder segment after it like a log, the hinder legs not moving at all. This was repeated several times. In fifteen minutes more sensibility was detected in the hinder segment. Here was a case which would have been pronounced very simple:—Division of the chord had seemingly destroyed all power of voluntary movement in the limbs below the section. The hind legs seemed paralysed. When the anterior segment was irritated, the animal crawled away dragging the posterior segment motionless after it. When this posterior segment was irritated, the animal did not crawl, but simply withdrew the limb or tail. If I touched the tail, or hinder leg, with acetic acid, the whole of the posterior segment (in which volition was said to be destroyed) began to move, and the legs set up the crawling action, attempting to push the whole body forward, which could not be effected, because the anterior segment was perfectly motionless. The hind legs, which never moved when the anterior segment was irritated, moved now in obedience to the spinal volition; and the anterior segment, which before seemed so energetic in its voluntary movements, was now perfectly unmoved. Each centre rules its own segment. If the cessation of motion of the hind legs, when the animal crawled, is a proof that voluntary power was destroyed in those legs, the cessation of motion of the fore legs, when the hind legs moved, is equally a proof that voluntary power was destroyed in the fore legs. The real truth seems to be that each segment has its own volitional centre. [Pflüger's experiments, which the author had repeated and varied, were here detailed, in evidence of the *choice* manifested by decapitated frogs.] I have at this moment a newt with the chord divided near the centre of the back. The operation was performed four days ago, and the animal has so far recovered from it that no spectator could distinguish between the voluntary power of its two segments. When the flame of a wax match is brought near the cerebral segment, the fore legs set to work, and the animal crawls away, dragging the hinder segment along. When the flame is brought near the spinal segment, the hind legs set to work, and the body moves sideways, the anterior segment remaining perfectly quiescent. All other stimuli produce similar results. I venture to submit that the explanation proposed to meet this case, namely, that division of the chord produces two independent volitional centres, is far more consistent with the phenomena, than the explanation offered by the reflex theory: unless the actions of the posterior segment of the newt are evidences of sensation and volition, I know of no kind of evidence for the existence of such properties in the cerebral segment. * * * *

I will not occupy the attention of this Meeting with the recital of other experiments. Those already cited suffice to indicate the nature of the evidence on which I found my positions. And indeed I might rest on one simple fact as proof that the spinal chord is a sensational centre, namely, the fact that whenever sensibility is destroyed all actions cease to be co-ordinated. Every one knows how greatly our muscular sensibility aids us in the performance of actions; but it has apparently been forgotten, that if sensibility be destroyed in a limb, by section of the posterior roots which supply that limb, the power of *movement* will be retained so long as the anterior roots are intact; but the power of *co-ordinated movement* will be altogether destroyed. With diminishing sensibility we see diminishing power of co-ordination, the movements become less and less orderly; and with the destruction of sensibility the movements cease to have their co-ordinated harmony. Now in the cases I have cited it is clear that this power of co-ordinating movements—sometimes very complex movements—was nearly, if not quite, perfect in the decapitated animal; therefore if co-ordination implies sensibility, the conclusion seems inevitable that the spinal chord is a centre of sensibility. The whole case may be summed up thus:—1st. Positive evidence proves that in decapitated animals the actions are truly sensorial. 2nd. Positive evidence, on the other hand, seems to show that in human beings with injured spines the actions are not sensorial, but reflex. 3rd. But as the whole science of physiology presupposes that between vertebrate animals there is such a general concordance, that whatever is demonstrable of the organs in one animal will be true of similar organs in another—and inasmuch as it is barely conceivable that the spinal chord of a frog, a pigeon, and a rabbit should have a sensorial function, while that of man has none—we must conclude that the seeming contradiction afforded by human pathology admits of reconcilement. No fact really invalidates any other fact. If the animal is such an organized machine that an external impression will produce the same actions as would have been produced by sensation and volition, we have absolutely no ground for believing in the sensibility of animals at all, and we may as well at once accept the bold hypothesis of Descartes that they are mere automata. If the frog is so organized, that when he cannot defend himself in one way, the internal mechanism will set going several other ways—if he can perform, unconsciously, all those actions which he performs consciously, it is surely superfluous to assign any consciousness at all. His organism may be called a self-adjusting mechanism, in which consciousness finds no more room than in the mechanism of a watch.

On the Pressure of the Atmosphere, and its Power in modifying and determining Hæmorrhagic Disease. By JOHN MILLIGAN, *M.R.C.S.E.*

The chief object of this paper appeared to be to show that hæmorrhage was in many cases produced by extraordinary atmospheric pressure, numerous cases being adduced in which bleeding occurred coincidentally with the fall of the barometer, and for which no other cause was discernible. In order to obtain a more complete elucidation of the subject, Mr. Milligan recommended the establishment of a system of medical meteorology, to which medical men might contribute by constructing tables presenting all the meteorological elements involved in or affecting cases occurring within their own practice.

After explaining the nature and kind of the periodic variations of the barometer, Mr. Milligan stated that the superficies of a human body of the average size would measure nearly 2000 square inches, and consequently sustain a pressure from the atmosphere amounting to 30,000 pounds, or nearly 15 tons, and that this weight would vary from a ton to a ton and a half, according to the pressure of the atmosphere, as indicated by the mercurial gauge. It was the peculiar relations that this pressure bore to hæmorrhagic disease that Mr. Milligan proposed to investigate; and from numerous well-authenticated cases it was proved that a great number of attacks of epistaxis and hæmoptysis occurred simultaneously with a depression of the mercurial column: moreover, that as a general rule hæmorrhagic attacks may be anticipated at the periods that mark the horary oscillations of the barometer, and more especially those that are accompanied by a fall of the mercurial column. In support of these opinions Mr. Milligan adduced several striking facts, and from a registration of 184 cases of various kinds of hæmorrhagic disease, the attacks commenced at the following hours:—From 1 to 2 A.M., 15 cases; from 3 to 4, 7 cases; from 4 to 5, 32 cases; from 5 to 6, 43 cases; from 6 to 7, 70 cases; from 7 to 8, 9 cases; from 8 to 9, 7 cases. Mr. Milligan concluded by calling upon his medical brethren to keep records of barometrical measurements and hæmorrhagic diseases, as it was only by a well-directed and systematic course of inquiry that the true bearings of meteorological phenomena to mortality and disease could be understood, and the perplexities and contradictions that invest correlative results could be satisfactorily ennunciated.

On the Influence of various Circumstances in causing Loss or Gain in the Weight of the Prisoners in Wakefield Convict Prison. By W. R. Milner.

The observations on which this paper were founded were made in the convict prison at Wakefield on prisoners between the ages of 16 and 50, confined in separate cells.

The cells have a cubic content of about 900 feet, and from 30 to 35 cubic feet of air is passed through each cell per minute.

The air is warmed in winter; the mean temperature of the cells for the year is 61° Fahr.; the highest monthly mean, 66·5, was in August; the lowest, 56·9, in March.

The diet is uniform, subject only to such alterations or additions as may be ordered by the medical officer in individual cases.

The prisoners are all clothed and exercised alike, and they are all kept at work; the greater part make mats and matting of cocoa-fibre; some work at tailoring and shoemaking, and a few are engaged in other employments.

The prisoners are all weighed on admission, and at the latter end of every month during their stay.

The observations extended over ten years; the number of men under observation was 4000. The average number weighed monthly 372, and the total number of weighings 44·004.

The results of these weighings were grouped with a view to exhibit the effect of a number of variable conditions, viz. season of the year, period of imprisonment, employment in prison, age, and height.

It was found that during the summer months the prisoners gained, and during the winter months, lost weight.

The change from loss to gain took place in March, and from gain to loss in September: these changes were not gradual, but abrupt.

During the first two months of their stay at Wakefield the prisoners gained weight, during the second two months there was a large loss of weight; a small loss occurred in the third period of two months; subsequently to this there was a steadily increasing gain, owing probably in a great measure to the extra diet given to those who were falling off the most.

The effect of muscular exertion was very clearly shown; as it appeared that while the men employed at sedentary work, such as tailors and shoemakers, gained on the average nearly two pounds per man during their stay, those who worked at coir-matting weaving, which is a very laborious employment, lost nearly seven pounds. Of the former it had been found necessary to give extra food to 26 per cent., while 60 per cent. of the coir-matting weavers had extra food given to them.

In the groups formed according to age, it at the first glance appeared that the younger and older prisoners gained weight, and that the middle-aged lost; but when the numbers were corrected for the quantity which each group ought to have gained by development, it was seen that the younger men, although heavier when they left the prison than when they entered it, really sustained a virtual loss of weight, gradually varying from nearly 5 pounds in those under 18 to half a pound in those between 25 and 40: the men above 40 gained weight.

The influence of height was, that the men below the average height gained weight, those about the average remained stationary, and those who were above it lost.

On the Form of the Eyeball, and the relative position of the Entrance of the Optic Nerve into it in different Animals. By T. Nunneley.

The author observed, that the orbits are much larger than the eyeballs, and that their axes diverge considerably in an outward direction, while those of the two eyes are perfectly parallel. The eyeballs lie in the fore-part of the orbits, and according as they are more or less prominent, and more or less covered with the lids, do they appear to be larger or smaller. The eye of the infant is larger, in proportion to the size of the body, than that of the adult; but it is by no means certain that the eye of the male is larger proportionately to the size of the body than the eye of the female. By some anatomists the human eye is described as a spheroid, the diameter of which, from before to behind, is greater than in any other direction. He had measured a great number of eyes, of the human subject as well as of animals; and he found that, wherever there was a departure from the spherical figure, it was in the direction contrary to that which had been commonly stated. In some instances the difference between the two diameters was scarcely perceptible; in all, where a distinction was observed, the transverse was the greatest. He had prepared a set of tables (which were printed), containing the result of the measurement of 200 eyes of various creatures. In conclusion, Mr. Nunneley said—"The measurements, I think, clearly prove that whatever part the fibres of the optic nerve play in the phenomena of vision,—and they, in all probability, only convey to the sensorium the impression received by the true retinal elements,—the greatest number of them are distributed on that part of the eyeball where there is the greatest range of vision, and that the largest expanse of retina is on that part of the ball opposite to where objects are placed, and consequently it is where the visual images of them must fall. Thus the extent of vision is always in conformity with the space of retina on that side of the optic nerve; and as the rods and cellules appear always to correspond in abundance with the fibres, that side of the retina which receives the greatest number of images is most exercised; or where the range of vision is the greatest, is always the largest. That this is a fact I think a careful comparison of the position of the eyes in the head, the size of the eyeball, and the exact position of the entrance of the nerve into it, with the mode of life and habits of various creatures, will render more obvious than a casual glance would do. To mention only a few instances as illustrations:—Man, from the erect position of his body, the horizontal placing of his eyes, and his habits, has a more panoptic range than any other creature (of course in this consideration all motions of the head, neck, and body of the animal must be excluded, and those of the eyeballs alone admitted). In him the optic nerve enters the ball not far from the centre, leaving, however, a somewhat shorter space on the inner and lower parts of the retina than on the upper and outer. Now, while man enjoys a free range of vision *above* the horizontal line, there are far more occasions for him to look at objects below than above this line, and thus mere visual images are projected to the upper and outer sides of the entrance of the optic nerve oftener than to the inner and lower sides of this spot. In the pig, who sees at no great range before him, and who seeks his food with the snout almost always in the ground, whose head and eyes are consequently for the most part downwards and near to the ground, the nerve enters the ball more outwardly and much lower than it does in man. The pig wants not to see far before him, but he does require while grubbing to look behind him, from whence danger comes. So with the timid herbivorous animals; look at the entrance of the nerve in the bullock and sheep, who pass so much time with the head in a dependent position near to the ground with the eye directed upon the surface, in open plains, where danger usually comes from behind; in them the upper and inner sides of the retina are much larger than the lower and outer portions, while in the deer who live in more wooded places, where danger is also from the front, but who, like the bullock, has the head downwards in feeding, though the inner or anterior side of the retina is still larger than the posterior, it is so to a much less extent than it is in the bullock—while the upper portion still continues as proportionately large as it is in sheep and bullocks. On the contrary, in the horse, who is not so preyed upon, who carries the head erect, and observes all around, the nerve enters the eye more nearly in the axis. In birds, with few exceptions, the upper portion of the retina is much more considerable than the lower parts, but the anterior and posterior portions vary much in different genera. Those whose locomotion is performed principally by the feet, and whose range of habitation is very small, as the common fowl and turkey, have the inner or anterior portion very considerably greater than the outer or posterior. Those birds whose range is greater and who use the wings for progression, but do not wander very far, as the grouse and partridge, have much less difference in the two portions of the retina; while in those birds whose flight is far and prolonged, as the crow, rook, swan, goose, and duck, the entrance of the nerve is very nearly in the centre of the ball. So in reptiles:—in the turtle, who only requires to see immediately before and under him, the outer and upper portions of the retina are very much the larger. In the more active alligator, frog, toad, and chameleon, while the upper portion maintains its size, the outer and inner parts are more nearly equal. In those creatures whose habitation is for the most part underground, as the shrew and the mole, the eyes are so small as to have led Majendie to assert that the mole is without the organ altogether, which is not the fact; for I have found all the essentials of an eye, even true retinal elements, optic nerve, and a well-developed choroid. Yet the organ is so minute and concealed by the skin and hair, as probably only enables the creature to discern the light, which is all that it requires; for, living underground, where it seeks its prey, it obviously must depend upon the acuteness of other senses than of sight for its living. Though in the individual there is usually some proportion between the size of the eye and the body, taking different classes and genera, the size of the animal is a very little guide to that of the eye, the proportions between the two being determined by other considerations than that of the bulk alone of the creature; for though, as a whole, the eye in fish bears a larger proportion to the whole body than it does in other divisions of the animal kingdom, and the eyes of birds are, as a class, much larger than those of mammalia or reptiles; yet amongst the different genera of all these classes there are very great differences, determined, apparently, by the following considerations, amongst others not so obvious. When the creature lives in feeble light, yet moves actively about, and is guided in its locomotion by the sense of sight, as in nocturnal birds and animals and fish, the eye is very large, apparently to take in a large quantity of the feeble light; on the contrary, where the creature is guided in its movements by other senses, then the eye is very small, as in the bat, the mole, the shrew, and the eel. Where vision penetrates to a long distance, and where the eye enjoys great power of overcoming the aberration of parallax, the eye is large, as in rapacious birds. When the brain and intellect are more developed, the size of the eye diminishes, and the two eyes become more parallel, as in man and the higher mammalia. Where animals are feeble, timid, have but little defensive power, and are preyed upon, the eye is usually very large,—as in the hare, the conies, the whole deer tribe, and many of the other ruminants. Where the animal is not predaceous, and its size and strength are such as to protect it from being preyed upon, the eyes are commonly small,—as in the whale and the elephant: in the latter the eye is even smaller than it is in the horse, and scarcely larger than in the eagle.

On the Structure of the Retina at the Punctum Centrale, or Foramen of Sœmmering. *By* T. Nunneley.

The author defined this *punctum centrale retina* as a small dark circular spot, $\frac{1}{84}$th of an inch large, situated exactly in the axis of the eye, and $\frac{1}{10}$th of an inch external to the entrance of the optic nerve in the living human eye; after which he proceeded in great detail to give what he considered to be the correct anatomy of this part of the retina.

On the Structure of the Choroid Coat of the Eye, and more particularly on the Character and Arrangement of the Pigmentary Matter. By T. Nunneley.

The choroid coat is the dark tissue interposed between the delicate sentient retina and the hard, dense sclerotic, and co-extensive with the latter. It begins at the entrance of the optic nerve by a round aperture, with a distinct edge, in close apposition with the nerve, but not organically connected with it, and passing forward as far as the junction of the sclerotic and cornea, where, as choroid proper, it terminates. It there comes in connexion with the ciliary circle or muscle, the ciliary body and the iris. The choroid is essentially a vascular membrane, being made up of blood-vessels, colouring matter, and a modified white fibrous tissue. The choroid universally pervades the pigmentary nigrum, and is of a deep bronze colour, approaching to black. The pigment was described as consisting of two distinct forms of cells; on the inner surface the choroid, of true hexagonal cells; and in the tissue, and on the posterior surface, of stellate cells. The use of these cells was to destroy the light as soon as it had acted on the retina; and they were the most perfect absorbers of light of any substance in Nature that he knew of. From the account he gave of the arrangement of the pigment, it afforded what he considered a satisfactory anatomical explanation of an abnormal condition of the eye which had hitherto not been understood, viz. *Muscæ volitantes*. The figures of those motes he believed to resemble exactly portions of the choroid coat when teazed out; and they might be expected to appear and disappear with the varying condition of the vessels arising from disordered stomach or the cerebral circulation, and be cured by whatever corrects those conditions; or the muscæ might result from different organic changes in the choroid coat, which are incapable of being removed.

On the Results obtained from an Extended Inquiry into the Quantity of Carbonic Acid evolved from the Lungs under the Influence of various Agents. By Dr. E. Smith.

The author gave a general account of a large series of experiments in which he had sought to determine the true amount of carbonic acid expired and of air inspired, with the rate of pulsation and respiration under numerous conditions, as, for example, in the twenty-four hours with the ordinary meals, during sleep, with different and definite kinds of exertion, during a prolonged fast, at various periods of the year, and under the influence of all ordinary kinds of food when taken separately and alone. He had collected all the carbonic acid expired during eighteen consecutive hours, with short intervals for meals, and had determined the amount expired in profound sleep in the night, viz. one-half of the average quantity of the day. There was a very slight and gradual increase after 3 A.M. until the hour of breakfast, and during the day there was always a rapid increase after each meal, and particularly after breakfast and tea, followed by a subsidence to the original amount before the next meal, if the meals were not too frequent. Whilst fasting (twenty-seven hours), the quantity was uniform throughout the whole period.

He found that the quantity of carbonic acid expired varied most materially under the influence of different kinds of food, states of the atmosphere, season, &c. During the summer the respiration is ⅙th less than during the colder months of the year; and although the skin exercised most important functions, he found that it was not vicarious of the action of the lungs in the expiration of carbonic acid; for while the lungs expired 600 grains, the skin threw off only 6 grains. The increase in the quantity of carbonic acid after partaking of arrow-root was very small, but it was much greater after eating oatmeal and rice; whilst wheat flour produced the greatest quantity, though the increase was less enduring than with oatmeal and rice. Tea, coffee, cocoa, and chickory were found to be respiratory exciters, and consequently increased the waste of the system, and could not be classed as food. As tea also induced perspiration, it was most valuable as a remedy against the action of heat, and would also be useful in cases of drowning and interrupted respiration. Tea caused the evolution of much more carbon than it supplied. Brandy, sometimes administered in cases of drowning, had the very opposite effect to that desired, since it lessened respiration; whereas tea increased the action both of the lungs and skin. If the object were to prevent the waste of the system, then alcohol might be useful, and tea would be improper. Both sugar and milk greatly increased the respiratory functions. The experiments made showed that those who were more susceptible of the influence of heat, were the least able to bear change to hot climates; and if this were borne in mind, it would be found of service to those who might contemplate going abroad.

On the Methods hitherto adopted for the Determination of the Carbonic Acid contained in the Expired Air, with the Description of a new Method. By Dr. E. Smith.

The author gave a brief account of the various methods which have been employed since the time of Lavoisier, and particularly those of Prout, Vierordt and Böcker;

of Andral and Gavarret, and of Scharling, and explained the particulars in which he regarded them as defective for physiological inquiries. He then described the apparatus and method which he had devised for the prosecution of his researches, and which he considered to supply some of the deficiencies which he has pointed out. It enabled the author to absorb the whole of the carbonic acid from any volume of expired air, however large or small, *during the period of expiration*, and to measure the inspired air for any period, however long or short. All the air admitted was inspired and none was respired twice; and it was applicable to experiments with the body at rest, or in active exertion, and during sleep or wakefulness.

The spirometer is a small dry gas meter of improved manufacture and registration, and moves with an inverted action. It was connected with a mask, which was just large enough to cover the nose, mouth and chin, and had valves suitably arranged to prevent a retrograde current, and to direct the expired air into the analytical apparatus. The analytical apparatus consisted of a "potass box," made of gutta percha, and divided into chambers and cells; so that a column of air of 2 in. $\times \frac{1}{8}$ in. was directed *over* 700 superficial inches of a strong solution of caustic potass, and remained in so close and prolonged contact with it as to be entirely absorbed during each expiration. There were the usual desiccators of sulphuric acid of large capacity, and the balances employed weighed to the $\frac{1}{100}$th of a grain with 7lbs. in each pan.

Microscopical Apparatus.

Mr. C. Brooke exhibited a microscope and case very completely fitted up, but having a stand of so simple and light a character as to render it very portable and convenient for use in the open air, at the seaside or elsewhere. It has a new and simple contrivance for the fine adjustment, and also for the rectangular adjustment of the secondary stage. A tourmaline inserted in one of the holes in the revolving diaphragm of a Powell's condenser, permits the use of polarized light, without any change of illuminating apparatus.

Mr. Brooke's instrument was fitted with a double lens, so that the power could be changed from a high to a low one without unscrewing the glass.

Mr. Ladd exhibited a microscope with an improved magnetic stage. The adjustments are effected by means of a steel chain; a moveable lever attached to the milled head gives a very efficient fine adjustment; and the facility of moving objects delicately by the hand afforded by the magnetic stage was remarked upon as a great advantage.

Mr. Warington described some additions which he had made to his portable microscope, by which living objects, as Polyzoa, &c., contained in glass bottles or small aquaria, could be examined with greater ease, over lengthened periods of time, and without disturbing them from their naturalized position.

GEOGRAPHY AND ETHNOLOGY.

The business of the Section was opened by Sir Roderick Murchison, *the President of the Section, in these words:—*

Ladies and Gentlemen,—Let me first congratulate our old members and adherents who are present upon having once more assembled in the great and flourishing county in which this Association had its origin. Twenty-seven years have elapsed since a small band of men, of whom I was one, met together in the city of York to establish the British Association for the Advancement of Science, and I rejoice to say that it was under the presidency of a virtuous and patriotic nobleman, the justly esteemed Lord-Lieutenant of the West Riding, the late Earl Fitzwilliam, and through the skilful arrangements of the Rev. W. Vernon Harcourt and Professor John Phillips, aided, indeed, by the eloquence of a fourth Yorkshireman, the Earl of Carlisle, then Lord Morpeth, that we gained our first position. Few as were our members, yet, even then, so heartily were we bound together in the good cause of the search after the truths of science, that we felt confident of ultimate success.

Holding our second meeting in the University of Oxford, the Association was then divided into six Sections; and to these another Section, or that of Statistics, was added at our third meeting in the University of Cambridge.

At that time and for some years afterwards Section E was appropriated to Medicine; but the cultivators of the healing art, justly perceiving that they had materials wherewithal to occupy a much wider field of research on subjects of national importance, felt compelled to leave us and establish their own Association. The number of medical men who have since annually met in large towns, to compare notes and evolve new discoveries, have indeed proved the soundness of the views of the seceders, who still left to us the cultivation of Physiology, which science thenceforward became attached to the Section of Natural History.

Thus abandoned, the symbol E remained for several years a dead letter, when it occurred to me that, the sciences of Geography and Ethnology having been hitherto very imperfectly represented in our Institution, it would be right to induce my associates who composed the General Committee assembled at Ipswich in 1849, then and there to fill up the blank by constituting a Section of Geography and Ethnology under this letter E; and of the new Section which was thus formed I had the honour to be the first President. In truth, the geographers and travellers who had been previously tacked on to the Geological Section, finding that they had no chance of a patient hearing among their associates the geologists, were dissatisfied; and, having myself a real love of both sciences, I felt assured that their separation, followed by this new amalgamation, would be highly conducive to the best interests of each. Then, again, the ethnologists were discontented at having no local habitation, and at being compelled to form at several meetings a sub-section, seeking for a meeting-room where they best could find it.

The union of geography and ethnology was indeed so natural, the subjects of which they severally treat are each so engaging and instructive, as well as popular, that the result has proved most satisfactory. In short, this Section has been, and I trust will continue to be, well-thronged by votaries, who rejoicing in the spirit of foreign research, come here to gather knowledge from the lips and writings of distant voyagers and travellers by sea and by land.

As President of the Royal Geographical Society I have truly good cause to be proud of the extraordinarily rapid increase in its members, and also in their quality and character; for we reckon among them nearly all leading public men, as well as the most distinguished explorers of foreign parts.

This success is indeed the natural result of the very constitution of the body politic of Britain and her extensive colonies; and, as there is no branch of science which is more intimately connected with the best interests of commerce and manufactures than that which makes us acquainted with the products and inhabitants of distant lands, so I confidently expect that in this rich and prosperous seat of industry, the memoirs and descriptions to be read will be duly appreciated; for, although we cannot expect to be every year honoured by the presence of such an explorer as my dear friend Livingstone, I know that you will be well satisfied with the communications which other distinguished men are about to make to you.

Lastly,—Gentlemen, I hope that your discussions will be carried on with that desire to elicit the truth, and that absence of any acrimonious feeling among amicable disputants, which has characterized in preceding years the proceedings of this flourishing Section of the British Association.

Notes of a Journey through parts of the Alatou, in Chinese Tartary. *By* T. W. Atkinson, *F.G.S.*

During my wanderings in Central Asia I came upon several large river-beds, in some of which there was no water; in others the streams were so small, that I found it difficult to account for their formation. I shall therefore commence abruptly with an account of a singular geological phenomenon—the evident trace of the sudden disruption of a mountain lake by a fearful earthquake at some distant period. Travelling along the steppe, near the foot of the Alatou mountains, I came to the brink of one of the dry river-beds frequently found in these regions. This was a large one, being not less than a mile and a half in width, and 130 feet deep, and the banks being nearly perpendicular. We succeeded in descending down a track made by deer and other animals. All the party, save two, had reached the bottom. As we stood watching these, the sand suddenly gave way under the feet of the last horse, and both man and animal rolled to the bottom, clear of each other, from a height of about 40 feet. We thought both were killed, but, on hastening to their aid, they rose to their feet; the horse gave himself a shake and began to kick and plunge furiously, and the man burst into a fit of laughter. All hope of returning by this track was now at an end, and we rode on, making vain guesses as to what had become of the torrents which had scooped out this formidable hollow. Sand and pebbles covered the greater part of the surface; near the middle we found several pools of fresh water, surrounded by beds of fine sand, on which were the footprints of many animals of the deer tribe, and among them the huge paws of the tiger. A little further we found a broad bed covered with large stones, over which a stream was running rapidly, rendering it difficult to ford. The opposite bank proved as high and as abrupt as the one we had descended, and gave us much trouble.

After riding about eight miles along the steppe, we reached the great ravine; having passed some rocky masses, the rugged mountain jaws burst upon us in all their grandeur. This was a terrific rent; the dark purple slate rocks had been riven asunder by the granite, and heaped up into craggy precipices of enormous height. In some parts the rocks were broken into sharp points, in others they were piled up like huge towers, overhanging the base of these mighty cliffs. To add to the wildness of the view, three large eagles were soaring far above our heads, and several others were perched on the crags. Far up in this pass we found that part of a tribe had pitched their yourts on some grassy slopes, at a point where the gorge branched off in two directions. We slept here, and darkness prevented me seeing the objects around. On turning out in the morning, I stood gazing in silent wonder at the scene before me. Immediately opposite, and about 300 yards from me, rose up a mighty mass of dark basaltic rocks to a much greater height than the distance from me to them. They were pillared and split into most curious forms—some of them like watch-towers guarding the pass. These rocks divide the gorge, which branches off to the south and east. Looking up the southern branch, the eye rested on the snowy peaks near the source of the Actou, and up the other were seen the dazzling peaks among which the Bascan has its source; while near me shrubs and flowers were hanging from the clefts, showing that spring was adorning these rugged forms in all her beauty.

I found difficulties in the way of obtaining a guide; the danger that beset the route I proposed to take were so great that the only man who knew the country refused to accompany me, but on showing him as a reward a flask of gunpowder and a few balls, his eyes sparkled with delight and his objections vanished. Shortly all were prepared, and we rode up the southern branch, passing the base of the basaltic cliffs, from whence the view down the gorge was savagely grand. After riding two hours we arrived at a part of the pass so abrupt that we could not ascend on horseback; even on foot it was difficult to scramble up. At last we reached a level space about 20 yards long and 4 yards in width. A scene was now before us that few could look down upon without a shudder. We were standing on the brink of a precipice, and looking into a fearful chasm. The rocks were dark purple slate, with a few shrubs hanging from the clefts; yellow and green moss covered the ledges, and at the bottom was a small lake, the water appearing of inky blackness, while to the south the mountain was so steep that it seemed impossible to ascend.

We began our ascent, going in slanting lines, gaining but little at each tack, and turning our horses with difficulty. As we ascended higher, each turning gave us a deeper view into the terrible abyss, with nothing to stop either man or horse should either slip. After great toil and no little anxiety, we reached the top. Our ride was along a rocky ridge for several miles, from whence we obtained a splendid view of the snowy chain of the Actou stretching to the east and west. Its vast glaciers and high peaks were sparkling like rubies in the setting sun; just at dusk we reached some large picta trees, and encamped for the night. Early in the morning we proceeded onward, when I saw, near the source of the Bascan, a very high peak, which had evidently been conical in form, and this had been torn asunder. One-half only was standing; the rent was curved, and the upper part overhanging. No snow could rest on this precipitous face, and the rocks appeared a dark purple. The snow that had been accumulating on this mountain for thousands of ages, was riven into perpendicular cliffs, 700 or 800 feet high, appearing like pentelic marble. We had now ascended about 1000 feet above the valley in which we had slept, and instead of rich grass we were on mossy turf, with the rhododendron and chrysanthemum creeping among the rocks, and covered with large bunches of beautiful yellow flowers. At length we reached enormous masses of green slate shooting up into high pinnacles; passing round these, we came upon a scene of terrible disruption and desolation, where rocks had been uprooted and hurled down into one chaotic mass, of a most fearful effect; extending to the brink of a vast rent that had cut the mountain asunder. A terrible convulsion must have taken place here. I had felt the heaving of the ground during an earthquake when in a valley to the westward, and had listened to the awful sound as it approached, deep in the bowels of the earth, and had apparently passed beneath me. I had heard the appalling subterraneous thunder as it rolled through the mountain,—now I beheld the terrific effects of one of these fearful visitations. Beyond this point the horses could not go; we dined, and our friends returned to their aoul.

The guide, two Cossacks, and myself began to descend, clinging as well as we could to the projecting points, till we gained a narrow ledge extending along a precipice: the guide led the way to a break in the rocks. Here a part of the cliffs had fallen, forming a stony slope, both steep and dangerous. After some slips and bruises we reached another small terrace, covered with bushes and plants. Continuing our way downward, and scrambling over many difficulties, we reached the bottom of the gorge, whose sides were 1000 to 1200 feet high. Following this ravine we reached a deep valley, about fifteen miles long and four miles wide, surrounded by mountains varying from 5000 to 7000 feet in height. This had been a deep mountain lake, proved beyond all doubt by the sand and shells spread over its bed. I also found the water line on the cliffs, showing that the depth was 560 feet.

Nearly opposite to the gorge by which we had entered there was another in the mountains to the north. On reaching it I found this was also a deep and narrow ravine, and no doubt formed by the earthquake; through this the water had rushed, draining the lake, and had formed the great water-course on the plain. We shortly entered the chasm, which I found was about 120 yards wide, covered with fallen rocks, among which a torrent was foaming with great fury. Our way was a rough and dangerous one; sometimes several hundred feet above the stream, and then descending nearly to the level of the water. At last we reached a spot beyond which to all appearance we could not proceed. We were now a little above the torrent, which was hidden from our view, and close in front of us the rocks rose up like a wall to an enormous height. A loud roaring of the water was heard, which induced me to suppose it was rolling over a deep fall. The old guide told me it was Shaitan's cavern swallowing up the river. The mouth of the cavern was formed by a rugged arch about 50 feet wide and 70 feet high. The river entered this opening in a channel cut into the solid rock; it was about 30 feet wide and 10 feet deep. A ledge of rocks, about 12 feet wide, formed a terrace along the edge of the stream, and just above the level of the water. When my astonishment had somewhat subsided, I prepared to explore the cavern by placing my packet of baggage and my rifle on a rock, and the two Cossacks followed my example. The guide watched these proceedings with great interest, but when he beheld us enter the cavern he was horrified. Having proceeded about twenty paces the noise caused by the falling water was fearful, and a cold chilling blast met us. From this point the cavern extended both in width and height, but I could form no idea of its dimensions. We cautiously groped our way on in the gloom for about eighty yards from the entrance, when we could see the river bound into a terrific abyss—"black as Erebus,"—while some white vapour came wreathing up, giving the spot a most supernatural appearance. Few persons could stand on the brink of this gulf without a shudder; the roaring of the water was dreadful as it echoed in the lofty dome. It was impossible to hear a word spoken: nor could this scene be contemplated long,—there was something too fearful for the strongest nerves, when trying to peer into these horrible depths. We turned away and looked towards the entrance; for a short distance the sides and arch were lighted up, but the great space and vast dome were lost in darkness. I sat down about fifty yards from the entrance, and in the twilight made a sketch of the scene. On leaving the cavern we passed round some jutting rocks, and then entered the narrow chasm beyond. Its bed was covered with large and small rounded stones—proving that water had once flowed through this part of the gorge, and I have no doubt it still does during the great storms in the mountains. As we proceeded onward, the ravine narrowed into a mere rent, with overhanging crags, rendering the place dark and gloomy. Our progress was slow and difficult, and we encountered many real dangers. Having emerged from the ravine, we looked down on the last low ridge; this appeared about three miles across, and at a short distance beyond we saw the fire of our companions blazing brightly. From this place the descent was steep; we hurried on, and shortly afterwards I was sitting at our camp fire, not sorry at having safely concluded an adventurous day's journey of sixteen hours; but the toil was not unrewarded: I had convinced myself that the water which had burst from the lake had formed the enormous channel through the plain.

Notes on the Russo-Chinese Frontier and the Amoor River. *By* W. G. Blackie, *Ph.D., F.R.G.S.*

The author remarked that the river Amoor claimed attention in consequence of the command of its navigation having passed into the hands of the Russians, by whom it had been opened to commerce and employed as a means of transporting provisions, munitions of war, and supplies of troops to her forts on the Pacific. It was one of the largest rivers in Asia, being only exceeded in length by the Yangtze in China, and the Yenessei and Lena in Siberia. From having direct communication with the North Pacific Ocean, it was superior as a commercial highway for conducting intercourse with foreign countries to the other rivers of Northern Asia, all of which flowed into the almost inaccessible parts of the Arctic Sea. After describing briefly the origin and general course of the river, which is navigable for steamers throughout its whole course to the junction of the Shilka and the Argun, a distance of probably 1500 statute miles, the paper proceeded to give a sketch of the history of the Russian settlements in the Amoorland, and their relations with China from the middle of the 17th century to the opening of the Amoor to Russian navigation, ceded by the Chinese in 1847, and the subsequent establishment of the fort of Nikolajewsk, at the mouth of the river. The advantages thus gained by Russia were made apparent in 1854 and 1855, when large stores of munitions of war were transported from Siberia to Shilkinsk and thence down the Shilka and Amoor to the North Pacific, at a saving of nearly 3000 miles of land carriage. A more detailed account then followed of the chief features of the river, the territory through which it runs, and the native tribes inhabiting its banks. In regard to the suitableness of the district for colonization, the genial climate prevailing at the southern bend of the Amoor was adverted to, as evinced by the existence of the wild-vine, and the production of an excellent quality of tobacco. The season during which the river is open for navigation from the ocean was stated to be from about the middle of June to the commencement of October. At Kisi, however, the Amoor is free of ice for six months, while the Bay of Castries is open for eight months; and to ensure a longer season for navigation than is attainable from Nikolajewsk, the construction of a railway is said to be contemplated between Kisi and the Bay of Castries. The author remarked likewise on the great advantage likely to accrue to Russia from the facilities afforded by this river to East Siberia for sending her mineral and other riches to the ocean, and receiving foreign articles in return at a much lower price than formerly. In regard to the trade with China also, it was observed that a portion of the merchandise, now annually sent overland to Siberia by Kiachta, might in future be transported by sea to the mouth of the Amoor, and thence up the river to the interior of the country. Attention was directed to the circumstance of an active trade being already carried on by the United States with the Russian station at Nikolajewsk, and the inference drawn that such a commerce must be equally advantageous to Great Britain, the voyage from London, Liverpool, and Glasgow to Nikolajewsk being as short as from New York; while from Singapore, Hong-Kong or Vancouver's Island, it is shorter than from San Francisco.

Notice of the Kanikars, a Hill-Side Tribe in the Kingdom of Travancore. By Astronomer BROUN, *F.R.S.*

On the Extension of Communications to Distant Places by means of Electric Wires. By Major-General CHESNEY, *R.A., D.C.L., F.R.S.*

The special object of his paper, he said, was to urge the necessity of multiplying the telegraphic communications of this country with all parts of the globe, and especially to propose a new electric route between England and America. He regarded electric wires as the pioneers of vast social changes; and if this view were correct, those which at present existed would form but a small portion of that great network of "swift messengers," which, if Great Britain desired to maintain her present mercantile supremacy, must speedily connect the principal parts of the world. This country, in fact, must follow the example of other countries; for, if it were content to see one portion of the Anglo-Saxon race far in advance of itself, and America enjoying the lightning-like intercourse with every portion of her vast continent, it would probably not remain equally satisfied to see Russia turning her vast means to such an account as might secure to her in future what she had in the case of the late treaty with China—priority by fully a fortnight of the most important commercial intelligence. After pointing out the many respects in which a country derived advantages from being able instantly to send communications to distant places, the writer gave a summary of some of the principal lines of telegraph which have been made in various parts of the world, or are in the course of construction. When addressing this Section of the British Association last year, on the importance of railway communication with India, he endeavoured to show that one line of electric telegraph might be laid down from headland to headland, along the Red Sea, and another through Arabia, partly in the bed of the Tigris. Both had been commenced, and each would probably meet with difficulties, and even interruptions, but only for a time, as the Porte was prepared to give the necessary protection. Ere long, he hoped, both would be in full operation, and, by having a double line, the communication would be kept up by one set of wires, in case of any accident to the other. He suggested, that for still greater security, a third line should be carried to the Persian Gulf. The latter would cross the Black Sea either from the Danube or Varna to Trebizond, which is shorter than the former line to Balaklava. It would pass without any difficulty or danger by Erzeroum, Tabriz, Teheran, and Ispahan to the Persian Gulf at Bushire. Moreover, the Shah is ready, and even anxious to do the Persian portion of this line himself. He thought that, independent of the advantages of having three lines, in case of any interruption, sufficient employment would be found for all three. It was evident that it was equally important that electric messages from this country to America should not depend upon a single cable. Full employment would be given at all times to several sets of wires; and as it was now certain that submarine communications with America were quite practicable, at least two additional cables should be laid down across the Atlantic. He thought that the difficulty caused by the distance between Iceland and Newfoundland might be greatly lessened by taking another route to the latter; namely, that of Iceland and Greenland, as by this line the greatest distance from land to land would not exceed 430 miles. The ice and the icebergs appeared to be the only difficulties likely to be encountered, and he thought they would not prove to be very serious. But as the latter when floated do not, and in fact *cannot* touch the bottom, it is the opinion of Sir Roderick Murchison, and other eminent men also, that the proposed line is eminently practicable.

On Dr. Prichard's *Identification of the Russians with the Roxolani. By* RICHARD CULL.

On the Physical Geography of the Neighbourhood of Bombay, as affecting the Design of the Works recently erected for the Water Supply of that City. By H. Conybeare, *C.E., F.G.S.*

The water is collected in an immense reservoir, the largest in the world, about fourteen miles from Bombay. This reservoir is made by damming up a portion of the valley of the Ghoper, and the full extent of it is 1394 acres. As the rains fall only once in a year, it is necessary to have a store of water for a twelvemonth's consumption, and this is now supplied. There were both engineering difficulties and facilities in the work undertaken, and these were described by the author. The 700,000 inhabitants of Bombay were now well supplied with water. There were self-closing public conduits in the streets for the supply of the poor. In these works it had been necessary to guard against offending the feelings or prejudices of the native inhabitants; hence in the valves and other appliances requisite in the distribution of the water neither leather nor animal fat could be used.

On the Effects of Commixture, Locality, Climate, and Food on the Races of Man. By J. Crawfurd, *F.G.S.*

The writer gave a review of the commixture of various nations, its effects on the mental faculties of the different populations, their physical characteristics, and language. He glanced at the effects of a change of climate upon any particular race. It did not appear, he said, that colour and the more prominent physical attributes, or mental capacity, had any necessary connexion with climate; nor did he think that climate altered the physical form and mental faculties of a race transferred from its original locality to a new one. He then pointed out, at some length, that the varieties of climate had a great influence upon the mental powers of a people; and proceeded to consider, under the last head of his paper, the question of diet in relation to the physical and mental character of a people. The physical character of a race, he said, did not seem to be in any respect altered by the nature of the vegetable diet of which it partook, provided the quantity were sufficient and the quality wholesome; but when the question of the diet of a people related to mental development, the quality assumed an important aspect. No race of man, it might be safely asserted, ever acquired any respectable amount of civilization that had not some cereal for a portion of its food.

Observations on the Lake District. By J. Davy, *M.D., F.R.S.*

In this paper the physical geography of the Lake District was chiefly treated of in relation to the varied beauty of its scenery, the peculiarities of its climate, and the character of its native population. Its beauty was referred to several circumstances, such as the admirable intermixture of the wild and cultivated, of lake, mountain and meadow; the graceful forms of the lower hills (attributable to glacial action) contrasted with the asperities of the higher, the mountain ridges and peaks; the youthful freshness of the woodlands, chiefly coppice, carefully attended to and regularly cut, not without admixture of ornamental planting. Its climate was described as most remarkable for summer coolness and winter mildness, for the large amount of rain (partly the cause of both) without unusual frequency of showers, and with moderate dryness of air, connected with absence of clay and a rapid drainage. The people of the district, chiefly pastoral in their occupation, of robust make, and of Norse origin, were made mention of as marked for good sense, and for thrift in their dealings, rather than for imaginative power. In concluding, attention was called to the influence of localities on health, and to the beneficial effects of residencies at certain heights, approaching 1000 feet above the level of the sea. In proof of the salubrity of the climate (apart from the ill-drained towns and villages), the exemption hitherto of its dales from cholera was adduced, and the longevity of its dalesmen.

On Pacific Railway Schemes, as communicated by the Earl of Malmesbury *to the President of the Royal Geographical Society. By* Consul Donohoe.

On the Configuration of the Surface of the Earth. *By the* Rev. J. Dingle.

Assuming, on the usual grounds, that the earth is a body that has cooled down from a state of incandescence, the author pointed out how the natural consequences of that hypothesis are distinctly traceable in the present configuration of the earth, so as to afford a general sketch of its history. From the relations which the mountain systems bear to each other and to the land, he inferred that the germs of them had originated about the same time in the earliest period of the earth's crust. The currents of a primitive ocean, as determined by known physical laws and modified by the mountain systems already formed, appeared to him necessarily to have led to the formation of the great continents in their present position, and when taken in connexion with the vertical forces operating from beneath, to account for all their geographical and geological features so far as they have hitherto been investigated.

Language no Test of Race. *By the* Rev. G. C. Geldart.

First, in a *negative* point of view, it was attempted to show that language is too uncertain an ethnological test to be of any practical value. This was instanced by the complete discrepancy which exists at this moment between the races and the languages of the British Isles. Cumberland and Cornwall, for example, in language, agree with London, and disagree with Wales; while, as to race, it is directly the reverse. Also, by the agreement in speech, notwithstanding the wide disconnexion of race between the Israelites and the Canaanites—the genuine Arabs and the Arabic-speaking populations in Asia and Africa—the Turks and the Greek-Christians in Anatolia—the Romans and their subjects in Spain, Gaul, Etruria, &c.—the Germans and the Sclavonians now absorbed by them in Prussia and North Germany—the Bulgarians and the Sclavonians,—the Magyars and the Ckomanians—and by many similar examples; the accumulative evidence of all amounted to this, that since in so many cases where the ethnological indications of language can be compared with the actual testimony of history, the latter completely contradicts the former; "a common language is" not even "*prima facie* evidence in favour of a common lineage."

It was remarked that the probability of language being a fallacious test of race must increase in direct proportion to the complexity of the particular race's experiences. But since it is plain that without the aid of history we can never calculate the degree of this complexity (from the fact that all barbarous nations show signs of decadence from a lost civilization), there is no more ground in the case of the most savage than of the most civilized race, to assume that the existing language is the original one. In Australia, *e. g.*, the native languages are radically one; but this forms no conclusive proof of the unity of the races, in the absence of historical evidence of this one language having been in primitive times common to them all. Its diffusion may very possibly be the result of artificial influences of which no record exists.

Secondly, in a *positive* point of view, it was shown that in all the instances above cited, there had taken place between the races, a close assimilation of (1) Political, (2) Religious, (3) Intellectual, or (4) general Social relations, or of any, or all of these combined; and it was suggested that it is such an assimilation, and not unity of race, that unity in language rightly typifies. The principle was applied in detail. Thus, in Cumberland and Cornwall, the assimilation in language with London was exhibited as the result of a loss of that national feeling, the permanence of which in Wales has preserved the provincial Celtic; and not as the sign of a greater commixture of races in the two former districts than in the last. The community of language between the Abrahamidæ and the Canaanites was referred to their social intercourse from the time of Abraham's migration into Canaan, until Jacob's descent into Egypt. The prevalence of Arabic or Turkish, in countries where Islam is dominant, represented the extent to which the Mahometan conquest has affected the habits and institutions of its subjects. The existence of the Neo-Latin languages was interpreted as a mark of the eagerness of the Roman provincial to obtain the 'civitas,' and with it to adopt the 'Latinitas.' The Teutonic speech which has overwhelmed the Wendish and Prussian languages in North Germany was the measure of the military and political force of the Teutonic Order and the "Römische Reich." The Sclavonic of modern Bulgaria was attributed to the action of that church of which Cyril and Methodius were the founders; and the Magyar language in the Ckomanian districts of Hungary was accounted for by the contented adhesion of the Ckomans to the Hungarian constitution.

The sum of the whole was, that it is not safe to infer from affinity between the language of two nations more than this, that there was a time when there existed between them civil, religious, or some sort of social relations. Language was the product and token of a nation's political, moral, or intellectual, but not of its physical constitution. It would not reveal a people's genealogy, but its mental and social history. Should it ever be proved that all languages were derived from one original, the sole valid inference would be, that at some time one sovereign race had imposed upon all the rest its own political or social institutions, while the great question of the number of races would remain just where it stood.

A Short Notice of the People of Oude, and of their leading Characteristics. *By* H. M. Greenhow.

The Sepoys of the late Bengal army deserve a short notice. Drawn principally from respectable agricultural families in Oude, they were often the younger sons of such families. Fine, tall, athletic men, with handsome features generally, and well-knit frames, they were the very flower of the youth of Oude. Fond of their homes, and having occasional furlough—even if serving in the distant stations of the Bombay Presidency, or in Burmah—for the purpose of visiting them; enjoying sufficient pay, and the prospect of pension after faithful service; having, too, certain privileges of their own, more especially at the Court of Lucknow, before that Court was abolished, the Sepoys of Oude were a set of men honoured by their own people and trusted by their officers. When led in battle by the latter they were brave and faithful; on the march or in cantonments they were orderly and obedient; in private intercourse they were gentle and polite. Ignorant, bigoted, and prejudiced they always were; and to ignorance, bigotry, and prejudice may be in a great measure ascribed the ease with which, in the hour of trial, their ears were opened to the voice of treason, and they forgot their honour aud their oaths. The author added, that the treachery and cruelty which seem to be inherent in the Asiatic nature, and which no extent of education had as yet even modified in the natives of India, showed itself in the Sepoy character during the late mutiny in an unmistakeable and repulsive form. The paper gave various details in connexion with the characteristics of Oude and its inhabitants.

On the Geometrical Projection of two-thirds of the Surface of the Sphere. By Colonel H. James, *R.E., F.R.S., Superintendent of the Ordnance Survey.*

Two maps were exhibited which were drawn on this projection, and described by Colonel James. The hemisphere was first projected by Hipparchus 200 years before Christ, but this is the first time that a geometrical projection of more than a hemisphere has been made. One of the maps exhibited contained the North circumpolar regions, and all Europe, Asia, Africa, and America; the other contained the South polar regions and the Pacific Ocean, with a large portion of North and South America and of Asia. The peculiar advantage of the projection consists in the accurate representation which it gives of the relative position of all parts of the earth to each other, an advantage which no other projection possesses, and which cannot be obtained even from the inspection of a globe.

On the General Distribution of the Varieties of Language and Physical Conformation, with remarks upon the Nature of Ethnological Groups. By R. G. Latham, *M.D., F.R.S.*

The principle which he held was that, in ethnological investigations, the method which ought to be pursued was that of the geologist rather than the historian—the geologist, arguing back from effects to cause, rather than the historian, who trusts to testimony in preference to facts. He also especially urged that it was important to bear in mind what was a true principle in zoology and the natural history sciences, and not to trust too exclusively to one characteristic. He did not, he said, believe that in ethnology any great discovery would be made, and he thought it was better not to attempt to give any opinion as to the question of the unity or the non-unity of the human race.

On the Yang-tse-Keang and the Hwang-ho, or Yellow River. By WILLIAM LOCKHART, *F.R.G.S. Communicated by* DR. NORTON SHAW.

This river, it appeared, was called by the Chinese "The Girdle of China," and it traversed the whole of the centre of the empire, rolling its flood of water to the sea, through the richest and most fertile part of the country. Its importance to China could not be too highly estimated, and it might be safely asserted that there was no river in the world which had on its banks so numerous a population, amounting to at least one hundred millions of people, who were sustained by its waters in the pursuits of commerce and agriculture. There were more than 100 cities of the first, second, and third classes, and 200 towns and villages which could be approached directly from its water-way. From its origin in Tibet to its outlet at the sea, its course was about 3000 miles, the points being distant in a direct line 1850 miles, and the basin drained by its channel being nearly 800,000 square miles. The commerce of many of the places situate on the borders of the river was very important. Persons engaged in every variety of trade resorted to Han-Khow for the exchange of their respective commodities; men from the north and west, from Mongolia to Tibet and Sze-chuen, brought their wheat, rice, dried and salted vegetables of every kind, bamboo sprouts, horses, sheep, furs, skins, coal, lead, jade or nephrite, gold in large quantities, rhubarb, musk, wax, and various drugs of northern growth, and exchanged them for tea, silk, camphor, opium, various southern drugs, and above all, for very large quantities of Manchester and Leeds goods. The quantity of long cloth and cotton goods that passed through Han-Khow was probably more than half of the whole brought to China, and access to this spot was of great importance. It had long been much desired by merchants that they should be able to inspect personally the trade of this place and take part in it, as, from the accounts brought by native traders, it would appear to be one of the most important—if not the most important —mart in all Asia. The paper referred to other places situate on the river, and described their principal features.

Extracts from a Letter by MR. WILLIAM RUSSELL *to the President.*

The President gave some particulars, contained in a letter dated Simla, 24th of July, which he had received from Mr. William Russell, the well-known correspondent of the *Times*, confirming the rumours of the death of M. Adolphe Schlagintweit, at Yarkand. He (the Chairman) regretted to say that there was no longer any doubt of the death of this adventurous traveller. After penetrating as far as Yarkand, where no European had ever been before, he was living in the suburbs of that city at a period when a war broke out between the Yarkandese and the Chinese, and he was slain by a number of the former, who surrounded his house in the night-time. Fortunately the chief portion of his papers would be saved, M. Schlagintweit having left them, before proceeding to Yarkand, at a place within the range of British influence. His travels were of much importance, as no region so far to the north-west of India as Yarkand had been previously visited by a European. M. Schlagintweit and his two brothers had travelled by the authority and at the expense of the East India Company. The brothers Hermann and Robert did not penetrate as far as Yarkand, and had since returned to Europe; a sketch of their adventurous travels across the Karakorum and Kuen Luen chains to the North of the Himalaya having been given by Sir Roderick Murchison in his last Anniversary Address to the Royal Geographical Society.

On the Navigation of the Ucayali, an Affluent of the Amazons. *By* C. R. Markham.

A Geognostic Sketch of the Western Position of Timor. *By* Dr. S. Muller.

Reports to Her Majesty's Government on the Physical Geography of the Country examined by the Expedition exploring the South-Western Regions of British North America. *By* Capt. J. Palliser *and* Dr. Hector.

The communications alluded principally to the investigation which had been made with a view of forming a communication through the British dominions. The reports considered it very important that a route should be established through the British territory, for the encouragement of emigration, and the transport of the future produce from Red River and the Great Western plains to Canada. The Canadian Government had offered £5000 for the establishment of a route between Lake Superior and Red River, and an engineering party had already commenced a portion of it.

On the Geography of British North America, more particularly British Columbia, Frazer River, &c. *By* Norton Shaw, *M.D.*, *Secretary to the Royal Geographical Society of London.*

Dr. Shaw gave an account of the various discoveries which have been made in North America, alluding minutely to those made prior to, as well as since the cession of Canada by France to Great Britain in the year 1763, and then proceeded to describe the geographical position of the Frazer River, the boundaries and limits of British North America, the mountains of the coast, called the Cascade Mountains; the Rocky Mountains, and British Columbia. He attributed the earlier exploration of the interior to the French, rather than to the English settlers, the latter having confined their attention chiefly to agricultural pursuits. Dr. Shaw then referred to the rewards offered by Parliament for the discovery of a north-west passage, and to the explorations made by an organized association of the traders of Canada, under the name of the "North-West Company," whose right of trading they had not unreasonably supposed to be independent of the Charter of the Hudson Bay Company, since it had existed before the cession of Canada to England. Speaking of British Columbia, he said that the face of the country presented a succession of mountain ridges, valleys, and plains, the more fertile districts lying, for the most part, between the Cascade Mountains and the Pacific. That portion of the country which lay between the Cascade Mountains and the Pacific was subject to a remarkably equal temperature, the mean being about 54° Fahr. There was only about four months of winter, and all fruits and vegetables were as early as in Canada. In several respects the climate of the middle section was less favourable: it was subject to droughts, and was warmer in summer and colder in winter. The air, however, was pure and healthy. The eastern section, amid the snows of the Rocky Mountains, could not be praised for its climate. The western section was well adapted for agricultural and horticultural operations. The middle section was favourably mentioned; and in the course of his remarks about the Frazer River, Dr. Shaw stated that it abounded in fish, as also did the other rivers in the district. Geese, ducks, and water fowl were plentiful in the spring and summer. In the eastern section of the country wild animals of various kinds were met with in great numbers. After having mentioned the auriferous deposits lately discovered on the Frazer River, Dr. Shaw dilated upon the probable communication by water and rail through British North America *via* the Passes of the Rocky Mountains, connecting thus in future the dense populations of Western Europe with those of Eastern Asia.

Letter to Sir R. I. Murchison *on the Project of a Canal across the Isthmus of Kraw, which divides the Gulf of Bengal from that of Siam.* *By* Sir R. Schomburgk.

In this letter, Sir R. Schomburgk, Her Majesty's Consul at the Court of Siam, announces his intention of personally examining the nature of the ground which occupies the narrow Isthmus of Kraw, and separates the Gulf of Bengal from that of Siam.

On a Method for the Spherical Printing of Globes. By M. I. Joseph Silbermann.

The merit claimed for M. Silbermann's invention was, that by it globes could be made more cheaply, rapidly, and accurately than upon the usual plan. Two copper hemispheres are employed, in which small globes are cast entire, and large ones by partially filling them with a kind of pulp, and introducing an India rubber bag, which is inflated by powerful pressure; and in that way the pulp is forced into the crevices of the mould.

On the Lacustrine Homes of the Ancient Swiss. By M. Troyon.

The object of the paper was to direct attention to the remains of ancient cabins or houses built on piles on the banks and in many of the lakes of Switzerland. These dwelling-places had been erected so that they might be surrounded by water as a protection from wild beasts and the enemies of the inhabitants. Remains of flint arrowheads, stone axes, flint knives, and other rude articles were found, and were some indication of the state of civilization and knowledge to which the inhabitants had attained.

On the Formation of a Railway from the Atlantic to the Pacific Ocean, through the British Possessions of North America. By A. Whitney, *of New York.*

The writer commenced his paper by explaining at some length the reasons why he was convinced that the United States would never attempt the construction of any such line of railway, and then observed that, had his plan been adopted, the work could have been commenced on the western shore of Lake Michigan, where there were timber, materials, and easy communication with settlement and civilization, and everything to facilitate settlement on its line the lines: to connect with it from the Atlantic, passing through but two States, could from necessity have been made tributary to its operation and management from the Lake to the Pacific. Congress then had power over it, and all the streams could have been bridged; so that an uninterrupted communication from ocean to ocean would have been for ever after. A cargo of merchandise could have passed from the Atlantic to the Pacific without transhipment, and as the road from the Lake to the Pacific would have been free, except tolls necessary for operations and repairs, the charge for transit would have been so low, together with the great saving in time, that the commerce of Europe with Asia would have been forced over it. This was now all lost to the United States. The author of the paper continued by saying, he had never believed that a railroad to the Pacific could ultimately benefit either Europe or the Atlantic slope of America, unless the commerce of Europe with Asia could be made to pass over it, leaving England with her present manufacturing and commercial position and relations, and augmenting her power over both. The immense business which the commerce and intercourse between Europe and Asia would give to the road must, as a natural result, form a foundation for the employment of a densely populated belt from ocean to ocean, and as far as the soil and climate might suit, mostly an agricultural people. This belt would take the surplus population from Europe, and make the producers of food to exchange for English manufactures on one side and Asiatic products on the other, thus benefiting to a vast extent the population of both Europe and Asia, by giving to each the means to consume more largely of the other's products. If these great results could not be attained, what benefit to England, or to the United States even, could be looked for from a railroad to the Pacific? When he was last in England (in 1851) he found many warm advocates for the construction of a railway over British territory. It was then, as now, his firm belief that this work could not be accomplished through a wilderness so vast, except by a system of settlement and civilization to be connected with the work. He then found that on a line so far north the climate and lands would not be as well suited to settlement and culture as further south, on territory of the United States; but he had since examined the subject more thoroughly, and found a large extent of country on the British side well adapted to settlement and culture. At the Selkirk settlement, further north even than necessary for the line of the road, wheat, rye, barley, oats, potatoes, and even Indian corn, were cultivated to perfection, the yield large and grain fine, and almost the entire line on this side would be a good grass country. The Pacific side for some parallels was 10° milder. The British side was far the most favourable for constructing a railroad with much lower grades. From Lake Superior to the Rocky Mountain Range was almost a level country. Near 50° parallel the stream divided, running north-easterly and south-easterly, and north of 45° parallel the mountains sloped to the Arctic Ocean, and nowhere north of 50° did they elevate their peaks above 5500 feet, with many depressions practicable for a railway. Was not this, then, the route for the commerce between Europe and Asia? Mr. Whitney pointed out that there was excellent harbour accommodation at Halifax, on the Atlantic side; and Puget Sound on the Pacific side, and observed that these two places would form excellent depôts for the commerce of Europe, Asia, the American continent, and indeed the whole world. A cargo of merchandise might then pass from the Atlantic to the Pacific without transhipment or delay, and the actual distance from England to China was some 2000 miles less than any route likely to be fixed upon by the United States. Panama Railway and the projected railway across Mexico were truly great enterprises; but people were mistaken as to their probable results. They would certainly facilitate travel and intercourse with California, Oregon, and the Sandwich Islands, but not so with Australia, the other islands, China, and India; because the sailing distance from England and Australia, China, India, &c., was less round the Cape of Good Hope than *via* Panama. The distance from Canton to London *via* the Cape of Good Hope was 2000 miles less than *via* Panama. The writer said that the Panama railway had not in any way changed the position of the people of Europe or Asia, nor in any way given to each the means of consuming more of the other's products. The result of it, however, he believed would inevitably be the hastening of the great changes consequent upon the encircling of the globe with civilization and Christianity, and building upon the Pacific slope a nation which must control the commerce of all Asia. Let England, then, he concluded by urging, put forth her whole strength and build a great highway for the world over her own soil. It could be accomplished in ten or fifteen years, and, with modifications, on the plan proposed by him to the United States. It could be accomplished nominally without outlay of money by the nation, creating by its connexion with the settlement of its line the means for its own construction: it would add millions of wealth to the nation, and give to it the control, not only of the commerce of all Asia, but of that of the world also. With steam, the distance from London to China could then be performed in twenty-eight days; merchandise even could be taken in thirty or thirty-five days.

Notes on the Physical Geography of North-Western Australia. *By* J. S. Wilson, *Geologist to the North-Western Australian Expedition.*

The paper described the climate of that part of Australia as being hot for six months in the year, but not injurious to health. The country, it said, was fertile, and a large variety of luxurious grasses was found growing, one species of which was a kind of wild oats, from 3 to 6 feet high. The indigenous plants were more numerous and superior to those of Southern Australia. The characteristics of the natives were similar to those of the aborigines of the south of the country, and the writer was glad to say that, in Lower Victoria, at all events, there was no unfavourable impression upon the minds of the native population against the settlement of the English.

On the General and Gradual Desiccation of the Earth and Atmosphere. *By* J. Spotswood Wilson.

The writer drew attention to the fact, that those who had travelled in continental lands, especially in or near the tropics, had been forced to reflect on the changes of climate that appeared to have occurred. There were parched and barren lands, dry river channels, and waterless lakes, and not unfrequently traces of ancient human habitations, where large populations had been supported, but where all was now desolate, dry, and barren. He had been first led to a consideration of the subject by phenomena of this nature that had come under his own observation, particularly in Australia, and he soon discovered that desiccation, so very observable there, was too extensive and permanent to be explained by occurrences of an irregular nature. Remembering also that similar appearances had been observed in other parts of the world, for which no satisfactory cause was assigned, he had collected the observations of travellers in regard to various countries, and endeavoured, by the evidence they afforded in the failing of the water systems, to establish the theory of a general and continuous decline of the humidity supported by the atmosphere, and then to discover in the operation of some law of our terrestrial system the cause of desiccation in both land and atmosphere. After quoting largely from the works of various travellers and writers (amongst the latest of whom were Dr. Livingstone), and giving interesting descriptions of dried-up rivers and desolated tracts of country in Australia, Africa, Mexico, and Peru, which had formerly been inhabited by man, Mr. Wilson proceeded to give his own theory as to the cause of this desiccation, contending that the upheaval of the land, the waste by irrigation, and the destruction of forests, all of which had been put forward as the cause, were insufficient to account for what had been described. He remarked that the amount of aqueous vapours that can be borne by the atmosphere at any time must be in proportion to the mass of the atmosphere itself, from which it followed that a reduction in the mass of the atmosphere would produce a corresponding decline in the amount of hydrous vapours absorbed and supported. If, therefore, a physical operation, involving a waste of the atmosphere, could be discovered, it might be concluded that at least one cause had been found for its declining humidity. Agreeably with these conditions, it was learnt that a vast amount of the atmosphere, and of the ocean likewise, had been solidified. The rocks, in the history of their own formation, bore witness to the tendency to transmutation in the character of both. The elements of water were hydrogen and oxygen, and the atmosphere was composed of oxygen, nitrogen, and carbonic acid, in which hydrous vapours mingled in varying quantities, all of which had entered largely into the formation of rocks and minerals. The coal plants had absorbed largely all the elements of air and water, but particularly of carbon, of which coal contains on an average from 80 to 90 per cent. Carbon united with oxygen formed carbonic acid, which, combined with lime and solidified, formed more than two-fifths of all limestone rocks. Oxygen was said to form half of what is known of the material of the globe. Besides existing in air and water, it formed a part of most earthy substances, and of nearly all the productions of the animal and vegetable kingdom. The oxygen of the atmosphere was also gradually absorbed by all animal and vegetable productions, and by almost all mineral masses exposed to the open air. From such facts as he had adduced and others he could produce, Mr. Wilson concluded that there was a gradual solidifying of the atmosphere and water on the face of this terrestrial world, which he inferred was, in the usual course of geological changes, slowly approaching a state in which it will be impossible for man to continue an inhabitant; and remarked that as inferior races preceded man and enjoyed existence before the earth had arrived at a state suitable to his constitution, it is more than probable others will succeed him when the conditions necessary for his existence have passed away.

Notice of the Opening of a Sepulchral Tumulus in East Yorkshire. By THOMAS WRIGHT, *M.A.*

Setting aside the vague speculations on a pre-Celtic population of the island, the first Roman known to have visited it, Julius Cæsar, who appears to have been personally acquainted only with the latter settlers in the maritime district of the south-east, informs us that the interior was inhabited by a people much inferior in cultivation, who were reputed to be the original inhabitants of the island. This people, we learn from later writers, were called the Brigantes, who held a very large portion of the interior of Britain, including the whole of Yorkshire. There were Brigantes also in Ireland, and Mr. Wright adduced arguments to show that the British population of Yorkshire belonged probably to the Gaelic branch of the Celtic race, and not to the Cymric. He described what were known of the peculiar characteristics of this British population of the Roman occupation of Britain, and of the establishment of the Anglo-Saxons, and he pointed out the interesting characteristics of many of the supposed British interments in East Yorkshire, as belonging, he suspected, to the period of the independence of the British towns preceding the Saxon invasion.

He then read an account of the opening of an ancient sepulchral tumulus in the township of Bridlington, by Mr. Edward Tindall of that place. A skeleton was found, laid on its back, in a trench or grave cut in the chalk, with a rude urn which had been turned on the lathe. A flint spear-head was found, according to the description, in the skull, as though it had penetrated from the back of the neck to the jaw. Mr. Wright concluded by pointing out circumstances in this interment which were rather of a Teutonic character, than Celtic or Roman.

STATISTICAL SCIENCE.

Address by the President, Edward Baines, *Esq., on opening the Section.*

If the British Association were a theatre for intellectual display, I should shrink from occupying a chair in which I have had such distinguished predecessors. But if I understand the spirit of this Association, it is the simple, honest, earnest pursuit of truth; first, of truth in facts, and secondly, of truth in principles; and it would be quite foreign to that spirit either to attempt anything of display or to apologize for its absence. I shall be permitted, however, to welcome the disciples of economical and statistical science on their visit to this important centre of industry, where practical illustrations may be found of many branches of their subject, and where, I hope, there are many who can value their inquiries. After the remarks made last night by the President of the Association, it may seem superfluous to say anything further on the claims of that science which he prononnced to "bear more immediately than any others on the prosperity of nations and the well-being of mankiud." We must all have felt how unanswerably the President proved the value of economical and statistical science, when he referred to the department of vital statistics, and showed what terrific losses had been sustained by our army and navy and the army of France, from the neglect of sanitary rules. But I may just remark that what gave to the recent report of Mr. Sidney Herbert's commission on the health of our troops in barracks its resistless force, was the certainty and precision with which statistical researches enabled it to measure the amount of loss sustained, by comparison with the mortality in other classes of the population at the same ages. The report might have dwelt on sickness, on injudicious diet, on defective ventilation, on want of drainage, and so forth, and all such statements would have been pronounced to be exaggerations or errors; but when it applied the ascertained scale of mortality so as to prove that there were so many deaths in the thousand when there ought only to have been half that number, the definiteness of the figures and facts defied evasion, fastened on the public mind and conscience, and compelled immediate measures of reform. Those persons who have ignorantly charged upon political economy and statistics a disregard of moral considerations and of humanity, may now see how egregiously they were mistaken, and how the arithmetic which they thought so heartless is rising up as the most powerful advocate of the value of human life, of health, of domestic comfort, of temperance, of virtue, of proper leisure, of education, and of all that can purify and elevate society. I am glad to know that we shall have one or more papers on important points of vital statistics laid before this meeting. May I for a moment refer to another reproach thrown upon statistics, namely, that they may be so used as to prove anything? I hardly need say that it is unfair to argue from the abuse of a thing against its proper use. But it may be admitted, that there is sufficient ground for this reproach, in the negligent or dishonest use sometimes made of statistics, to call upon us for the exercise of great caution, so that in the first place we may be sure we have got all the facts that are essential, and in the next place that we draw from them sound and accurate conclusions. The statist ought to remember how liable are loose and defective masses of figures to be used by both sides in controversy, each picking up such as suit him wherewith to pelt his antagonist. It is valuable to collect facts, but it is still more useful to ascertain that they are exact and complete, and then so to arrange them that they may serve to build up some useful structure. A statist ought to lay a charge upon his conscience, as though he were sworn in the form of our old oath to speak "the truth, the whole truth, and nothing but the truth." Nor can we be too careful to reason fairly and soundly from the facts we may amass; for it is the facts of the statist and the doctrines founded upon them by the economist, which, to a great extent, guide our practical legislation, and thus affect the great interests of society. I cannot refrain from expressing my conviction, that as the science we cultivate has been shown to be favourable to humanity, so it is no less favourable to freedom. Within the last quarter of a century how busy has it been in knocking off all sorts of fetters from human energies!

It is, indeed, opposed by the interests which restrictions have created, sometimes manufacturing, sometimes agricultural; but in England at least its march in the path of freedom has been rapid and steady; and we may say of it, *vestigia nulla retrorsum*.

On the Woollen Manufacture of England, with special reference to the Leeds Clothing District. By EDWARD BAINES.

The author commenced his paper by observing that it was suitable, when the British Association honoured Leeds with a visit, that its members should receive some account of the great branch of manufacturing industry of which Leeds was the ancient seat, and which prevailed here on a larger scale than in any other part of England or of the world. It was peculiarly desirable that such an account should be rendered to this Section, because, notwithstanding the antiquity of the manufacture, its economy and statistics were by no means well ascertained. Though a large part of the raw material was grown at home, we had absolutely no reliable statistics of the amount of this famous product of the British Isles. It was hoped, therefore, that the present attempt to ascertain the facts connected with the woollen manufacture might not be without its use; and also that it might derive some additional interest from indicating remarkable modern changes in this department of industry, and explaining some peculiarities which at first sight perplexed the political economist. The woollen manufacture of Yorkshire was prosperous and advancing; but it could not fail to have been noticed that its progress was less rapid and extraordinary than that of other textile manufactures; and it might be well to show that this was to be ascribed to circumstances inherent in the nature of the fabric, and not to indifference and apathy on the part of those engaged in this branch of industry. The difference between the woollen and the worsted fabrics consisted chiefly in the woollen yarn being very slightly twisted, so as to leave the fibres at liberty for the process of felting, whilst the worsted yarn was hard spun and made into a much stronger thread. The feebleness of the woollen yarn made it more difficult to be woven by the power-loom than either worsted, cotton, linen, or silk, none of which was susceptible of being felted. The processes of the woollen manufacture are more numerous and complex than those of any other of our textile manufactures, and are performed by a much greater variety of machines and of workpeople. It was pretty obvious, the author remarked, that there must be proportionate difficulty in effecting improvements which would tell materially on the quantity or the price of the goods produced. There was still another fact which retarded the advance of the woollen as compared with other manufactures, namely, the higher price of the raw material, wool being about three times the market price of cotton and flax. Nor could sheep's wool be augmented in quantity so rapidly as raw materials which merely required the cultivation of the soil. But the economist might inquire how is it that the worsted manufacture has of late years increased so much more rapidly than the woollen, seeing that it uses the same raw material, sheep's wool? It was to be ascribed in part to very remarkable improvements made within these few years in the process of combing, which was now performed by machinery instead of by hand, and the cost of the process reduced almost to nothing,—in part to the greater simplicity of the other processes, admitting of their being carried on almost entirely in large factories,—but more than all to the introduction of cotton warps into the manufacture, which had not only cheapened the raw material, but had introduced a vast variety of new descriptions of goods, light, beautiful, cheap, and adapted both for dress and furniture. According to the last Factory Return made by the Factory Inspectors in 1856, and printed by the House of Commons in 1857, there were in Yorkshire 445 worsted factories and 806 woollen factories; but the number of operatives was 78,994 in the former, and only 42,982 in the latter. The average number of operatives in the worsted factories, therefore, was 177, whilst in the woollen factories it was only 53. The whole number of operatives returned in the census of 1851, as employed in these two manufactures in the county of York, was 97,147 in the worsted manufacture, and 81,128 in the woollen. Four-fifths of all the hands employed in the worsted trade were in factories, whilst only about half of those in the woollen trade were in factories. Everything tended to show that the worsted manufacture, like those of cotton and linen, had become an employment carried on by the machinery of large factories; and as mechanical improvements were constantly speeding the power-loom and the spindle, so that in worsted factories the power-loom had increased 67 per cent. in speed within the last ten years, and the spindle 114 per cent., manufactures thus situated must advance more rapidly than those which, like the woollen, were more dependent on manual labour. The woollen manufacture was surpassed in extent by the cotton manufacture at the beginning of the present century. It still held the second place in regard to the number of operatives employed, though not to the number employed in factories, in which it was surpassed both by the worsted and the flax or linen trades. In the woollen mills, between 1838 and 1856, the number of operatives increased 44 per cent., the horse-power employed increased 25 per cent., and the number of power-looms increased 572 per cent.; but still the other manufactures advanced with greater strides in almost all these respects. The author next referred to the sources from which the raw material, sheep's wool, is drawn, and to the remarkable changes which the present century has witnessed with regard to it. The wool was English, foreign, and colonial, and came from all quarters of the globe. Our largest supply was from the United Kingdom, but nearly half of the domestic wools was consumed in the worsted manufacture, and the other half was used for the lower kinds of woollen goods. Within living memory Yorkshire cloth was made exclusively of English wool, though Spanish wool had long been used for the finer cloths of the West of England. Now, however, English wool, from its comparative coarseness, was entirely disused in the making of broad-cloth. In the last half of the 18th century the import of foreign wool fluctuated from a little under to a little over two million pounds weight a year. In 1799 it was 2,263,666 lbs. But in the year 1857 the quantity of foreign and colonial wool imported was 127,390,885 lbs., of which 90,903,666 lbs. was retained for home consumption. As the exports of woollen goods did not increase in any proportion whatever to these figures, it was evident that the character of the cloth, both that worn at home and that exported, must have changed by the substitution of foreign and colonial for English wool. The foreign wool first used when this improvement in the quality of the cloth began, was that of Spain, the native country of the merino sheep. The total import of wool sprang up suddenly from 2,263,666 lbs. in the year 1799, to 8,609,368 lbs. in 1800; and of the latter quantity, 6,062,824 lbs., or more than two-thirds, was Spanish. After the French invasion of Spain and the long Peninsular wars, the quality of Spanish wool degenerated, and the quantity fell off; and its place in our manufacture was gradually filled by the wool of Saxony and Silesia, into which country the merino breed of sheep had been introduced in 1765. The German wool was still by much the finest used in any country; but as the merino flocks were introduced by Mr. Macarthur into our great Australian colonies, and were found to increase there immensely without any very great degeneracy in the quality of the fleece, German wool had in its turn to a very considerable extent been superseded by Australian. The following Table showed the imports and exports of foreign and colonial wool, at intervals of about ten years, for the last century:—

Foreign and Colonial Wool Imported and Exported.

Year.	Foreign wool imported.	Colonial wool imported.	Total imported.	Foreign and colonial wool exported.	Left for home consumption.
1766	1,926,000	....	1,926,000	....	1,926,000
1799	2,263,666	....	2,263,666	....	2,263,666
1800	8,609,368	....	8,609,368	....	8,609,368
1820	9,653,366	122,239	9,775,605	64,585	9,711,020
1840	36,585,522	12,850,762	49,436,284	1,014,625	48,421,659
1850	26,102,466	48,224,312	74,326,778	14,388,674	59,938,104
1857	44,522,661	82,868,224	127,390,885	36,487,219	90,903,666

The changes which had taken place in the sources of supply were shown in the following Table:—

Imports of Wool from the Principal Countries.

Year.	Spain.	Germany.	Australia.	South Africa.	East Indies.
	lbs.	lbs.	lbs.	lbs.	lbs.
1800	6,062,824	412,394	....	....	....
1810	5,952,407	778,835	167	....	....
1816	2,958,607	2,816,655	13,611	9,623	....
1820	3,536,229	5,113,442	99,415	29,717	....
1830	1,643,515	26,073,882	1,967,279	33,407	....
1834	2,343,915	22,634,615	3,558,091	141,707	67,763
1840	1,266,905	21,812,099	9,721,243	751,741	2,441,370
1850	440,751	9,166,731	39,018,221	5,709,529	3,473,252
1857	383,129	5,993,380	49,209,655	14,287,828	19,370,741

Here we see the decline in the quantity of Spanish wool imported from 6,062,824 lbs. in 1800, to 383,129 lbs. in 1857; the increase of German wool from 412,394 lbs. in 1800, to 26,073,882 lbs. in 1830; and its subsequent decline to 5,993,380 lbs. in 1857; the increase of Australian wool from 167 lbs. in 1810, to 49,209,655 lbs. in 1857; the increase in South African or Cape wool from 9623 lbs. in 1816, to 14,287,828 lbs. in 1857; and the increase in East India wool from 67,763 lbs. in 1834, to 19,370,741 lbs. in 1857. These were remarkable commercial changes, and they warranted the hope that we might ere long find in the East Indies, Australia, and Africa, sources of supply for the still more important raw material of cotton, produced by the labour of freemen, instead of being so dangerously and perniciously dependent on the slave-raised cotton of the United States. The imports of German wool had fallen off even to a greater extent than appeared from the above Table, inasmuch as there was now a large quantity of rag-wool, called shoddy and mungo, imported from Germany; and he was assured by Mr. Fonblanque, of the Statistical department of the Board of Trade, that no distinction was made at the Custom-house between the entries of the finest Saxon wool, which was of the value of 3*s.* per lb., and those of shoddy, which was only worth a few pence per lb. Since this paper was written, the Hon. Stephen Rice, Deputy-chairman of the Board of Customs, had assured him that shoddy should in future be entered separately from wool. Of the annual production of wool in the United Kingdom, there were, as had been said, no reliable statistics whatever, and the judgment of those engaged in the trade varied very widely. The balance of authority would dispose us to conclude that the annual produce of domestic wool must be between 150,000,000 lbs. and 200,000,000 lbs. If we took the medium, namely, 175,000,000 lbs. at 1*s.* 3*d.* per lb., which was about the average price of the last thirty years, the value of this great raw material produced at home would be £10,937,500. The judgment thus formed from a comparison of authorities had been exactly and unexpectedly confirmed by the result of careful inquiries and calculations, founded on the number of hands employed, the power of the machinery, and the estimated value of the goods manufactured. That result was that 160,000,000 lbs. is used by the woollen and worsted manufacturers, whilst the quantity exported in 1857 was 15,142,881 lbs., making an aggregate of 175,142,881 lbs. of English wool. The exports of English wool, both in the raw state and in the first stage of manufacture, namely, yarn, were great and rapidly increasing. Thus the farmer was deriving benefit from the freedom of trade, and English wool was resuming its flow through channels which legislation had closed for five centuries. It was for our manufacturers to take care that no other country made a better use of their native raw material than themselves.

The author then glanced at the history of this ancient manufacture up to our own times, and observed that they ought not in that Association and in that Section to withhold the honour due to the high intelligence, manly spirit, and wonderful disinterestedness of Lord Milton, afterwards Earl Fitzwilliam, who, whilst representing the great seat of the woollen manufacture, Yorkshire, advocated the removal of protection from the manufacturers, and, although one of the largest landowners, contended for the removal of protection from agriculture. It was a matter of just pride for this Association and for Yorkshire to remember that that enlightened and high-minded nobleman was the first president of the British Association. The woollen manufacture, in its various branches, was very extensively diffused. According to the last Factory Return, it prevailed in twenty-two counties of England, ten of Wales, twenty-four of Scotland, and six of Ireland. More than one-half of the operatives employed in the woollen factories were in the county of York, namely, 42,992 out of 79,081. The worsted manufacture, on the other hand, though for some centuries it had its chief seat in Norfolk, Suffolk, and Essex, had now obtained a remarkable concentration in the West Riding of Yorkshire. Out of 87,994 factory operatives in the worsted trade of the United Kingdom, 78,994 were in Yorkshire. The chief seat of the manufacture of superfine broad-cloth had for centuries been, and still was, the West of England, and especially the counties of Gloucester and Wilts. The population, and doubtless also the trade of the West Riding of Yorkshire, had increased much more rapidly both in the eighteenth and nineteenth centuries than those of Gloucestershire, Wiltshire, and Norfolk. Between the years 1801 and 1851 the population of Leeds increased 224 per cent.; Bradford 682 per cent.; Huddersfield 325 per cent.; Halifax 179 per cent.; and Norwich 88 per cent. The author apprehended that the principal advantages of the West Riding over Gloucestershire, Wiltshire, and Norfolk consisted, first, in the greater cheapness of coal and iron; secondly, in the larger body of men skilled in the making and working of machinery; and thirdly, in the facility of access to the great ports of Liverpool and Hull. But he inclined to think that the mere fact of Yorkshire having devoted itself to the manufacture of cheap goods had been as influential as any other cause.

The author next spoke of the general statistics of the woollen manufacture, and first

Woollen and Worsted Goods and Yarn Exported.

Years.	Manufactured goods.	Yarn.	Total Exports.
	£	£	£
	(Official value)		
From 1718 to 1724—yearly average	2,962,881	....	2,962,881
1740........	3,056,720	....	3,056,720
1750........	4,320,006	....	4,320,006
1760........	5,453,172	....	5,453,172
1770........	4,113,583	....	4,113,583
1780........	2,589,109	....	2,589,109
1790........	5,190,637	....	5,190,637
1800........	6,917,583	....	6,917,583
1810........	5,773,719	....	5,773,719
	(Declared value)		
1820........	5,586,138	....	5,586,138
1830........	4,728,666	122,430	4,851,096
1840........	5,327,853	452,957	5,780,810
1850........	8,588,690	1,451,642	10,040,332
1857........	10,703,375	2,941,800	13,645,175

of our exports to foreign countries. The earlier tables made no distinction between the woollen and worsted goods exported, and the later tables made the distinction imperfectly. Up to the year 1815 we had only the official value of the exports, which, however, probably did not vary much from the real value; from 1815 downwards we had the real or declared value. Before the year 1820 also, the tables included the exports to Ireland, though this fact was overlooked by most writers on the subject.

The experienced eye would see at a glance how for the last ninety years the natural progress of the woollen manufacture had been checked by the introduction of the cheaper material, cotton, and the unparalleled extension of its manufactures; of which we last year exported to the value of £29,597,316 manufactured goods and £8,691,853 yarn, making a total of £38,289,169.

Woollen and Worsted Goods and Yarn Exported from 1820 to 1857, distinguishing the classes of goods; with the declared value for 1857.

	In 1820.	In 1850.	In 1857. Quantities.	In 1857. Declared value.	Total declared value 1857.
Woollen Manufactures:—				£	£
Cloth of all kinds .... *pieces*	288,700	608,926	695,063	2,956,491	
Napped coatings, Duffels, &c. *pieces*	58,644	8,035	829	3,698	
Kerseymeres........ „	78,944	15,626	3,777	19,587	
Baizes .... „	37,183	23,727	15,474	51,017	
Flannel .... *yards*	2,569,105	2,833,898	4,892,442	283,750	
Blankets and Blanketings ..	1,288,499	6,461,224	8,118,596	576,489	
Hosiery (other than stockings)	..	£249,757	..	232,076	
Small wares (including rugs)	..		..	90,659	
Shawls................	..	..	..	194,756	
Total Woollen Goods......	..	..	..	..	4,408,528
Worsted and Mixed Stuffs:—					
Worsted stuffs...... *pieces*	828,901	2,122,397	2,568,482	3,325,564	
Mixed stuffs (worsted, cotton, and silk).......... *yards*	407,716	52,573,686	57,715,819	2,225,839	
Carpets and carpeting.. „	526,124	1,668,675	4,452,428	613,246	
Stockings...... *dozen pairs*	..	120,185	193,957	130,198	
Total Worsted Goods......	..	..	..	..	6,294,847
Woollen and Worsted Yarn, *lbs.*	..	13,794,225	23,980,704	2,752,386	
Do. do., mixed with other materials .... *lbs.*	..	..	723,744	189,414	
Total Yarn..............	..	..	..		2,941,800
Total Exports of Woollen and Worsted Goods and Yarn....					£13,645,175

It would be remembered that the year 1857 was one of great overtrading, and, as far as could be judged from the seven months of the present year, there would be a considerable falling-off in the woollen exports and a still greater in the worsted exports. The combined woollen and worsted exports formed about one-ninth of the entire export trade of the country. The woollen goods exported were of the value of £4,408,528, the worsted goods £6,294,847; and, as the yarn was nearly all worsted, the total worsted exports would be £9,236,647. These figures of course did not indicate the respective or proportionate values of the whole production of these two branches of the manufacture of wool, but only of the quantities exported. Including the domestic consumption, there was reason to think that the woollen manufacture somewhat exceeded that of worsted; but the figures of the table just given, especially combined with the considerations mentioned in an earlier part of this paper, would lead to the belief that the worsted manufacture would ere long exceed the woollen. In the attempt to estimate the entire annual value of the woollen manufacture, he had found difficulties on every side. All the elements for calculating the number of persons employed and the value of the goods produced were uncertain and defective. As to the number of persons employed, the census of 1851 made an approach to the truth, and was the best evidence we had; but it was not altogether trustworthy. He was disposed to think that we might estimate the earnings of each person employed in the woollen manufacture to support three-and-a-half persons, including himself, and in the worsted manufacture two-and-a-half; and at this rate the numbers supported in the respective branches would be as follows:—

Individual Workers in the Woollen and Worsted Manufactures, and estimated number of persons supported by them:—

	Individual workers.				Persons supported.
In the woollen manufacture..	150,000	×	3½	=	525,000
In the worsted manufacture..	125,000	×	2½	=	312,500
Totals..............	275,000				837,500

It must also be remarked that a larger proportion of persons in auxiliary occupations was connected with the manufactures of wool than with any other textile manufacture, owing to more than one-half of the raw material being raised at home, whilst the cotton and silk were wholly dependent on importation, and the linen almost wholly. The wages earned by the operatives in the woollen manufacture were good, and such as must afford the means of great comfort to their families, besides indicating a prosperous condition of the trade. He had been favoured with several tables of wages from houses of eminence in this neighbourhood, and he had the pleasure to know that they would be received by the statist as of great value. The following general statement might be received with entire confidence:—

Average Wages of Operatives in the Manufacture and Dressing of Woollen Cloth in the Leeds Clothing District. Supplied by Messrs. Gott.

Description of Operatives.	Sex, &c.	Wages per week.
Wool sorters	Men	24*s*.
Wool scourers, dyers, &c...	Men	16*s*. to 20*s*.
Slubbers	Men	27*s*.
„ overlookers......	Men	35*s*. to 40*s*.
Servers or fillers..........	Girls or boys—	
„ „	for 1 machine	5*s*.
„ „	for 2 machines	9*s*.
Billy piecers.............	Children........	4*s*.; half-timers 2*s*.
Cleaners and willyers......	Young men	12*s*. to 14*s*.
Mule spinners...........	Men	28*s*.
„ piecers	Girls or boys....	6*s*.
Warpers	Women	12*s*.
Weavers, hand-loom	Men	15*s*.
„ power-loom......	Women	10*s*. to 12*s*.
Overlookers and tuners....	Men	21*s*. to 28*s*.
Knotters	Women	7*s*. 6*d*.
Burlers	Women	5*s*. to 6*s*.
Millers	Men	18*s*. to 20*s*.
„ overlookers........	Men	30*s*. to 40*s*.
Dyers	Men	16*s*. to 18*s*.
„ foremen	Men	30*s*. to 60*s*.
Dressers	Men	20*s*. to 22*s*.
„	Young men	12*s*. to 16*s*.
„	Boys	4*s*. to 9*s*.
Dressed cloth burlers......	Women	6*s*. to 7*s*.
Drawers	Men	30*s*. to 40*s*.
Tenterers	Men	26*s*. to 30*s*.
Press-setters.............	Men	35*s*. to 40*s*.
Enginemen	Men	24*s*.

He felt justified in estimating the wages of operatives in the woollen manufacture at not less than 12*s.* 6*d.* per week on the average for men, women, and children; and this for 150,000 workers, would give an aggregate of £4,875,000 per annum. Mr. Baines then explained some circumstances relative to the Leeds clothing district, especially the great quantity of low woollens made in the Batley district, chiefly from shoddy or mungo, which was wool made from tearing up woollen rags and also from the waste of the woollen mills. He said that in drawing to a conclusion he must endeavour to estimate the annual value of the woollen manufacture of the kingdom. Uncertain as were several of the important elements in the calculation, he felt considerable confidence, arising out of the abundance of the materials before him, the care with which he had tested them, and the coincidence of several methods of calculation in bringing about the same result. The constituent parts of the value of the woollens manufactured in the United Kingdom were, 1st., the value of the raw material; 2nd, the value of other articles essential to the manufacture; 3rd, the wages paid to the workpeople; and 4th, the sum left to the capitalist for rent, repairs, wear and tear of machinery, interest of capital, and profit. His estimate was as follows:—

Value of the Woollen Manufacture.

	£
1. Raw material—	
lbs.	
75,903,666 Foreign and Colonial wool	4,717,492
80,000,000 British wool, at 1*s.* 3*d.* per lb.	5,000,000
45,000,000 Shoddy and Mungo—	
30,000,000 lbs. at 2½*d.* } 15,000,000 lbs. at 4¾*d.* }	609,370
Cotton warps, 1-50th of the wool	206,537
2. Dye wares, oil, and soap	1,500,000
3. Wages—	
150,000 workpeople, at 12*s.* 6*d.* per week	4,875,000
4. Rent, wear and tear of machinery, coal, repairs, interest on capital, and profit—20 per cent.	3,381,680
Total	£20,290,079

He would only, in conclusion, recommend the members of the British Association to inspect the Exhibition of Local Industry now open in this town, where they would be able in some measure to judge of the industry and skill of our manufacturers; and would express a hope that those manufacturers would never rest satisfied with any position they might have attained, but, stimulated and warned by what they had seen in the Great Exhibitions of London and Paris, would remember that they only held their prosperity on the condition of unceasing improvement.

On the Rate of Mortality in the Metropolitan Improved Dwellings for the Industrial Classes. By JOSEPH BATEMAN, *LL.D.*

On the Sanitary and Industrial Economy of the Borough of Leeds. By R. BAKER, *Factory Inspector.*

In the year 1080, Leeds proper was a farming village, with an estimated population of somewhat less than 300, including 27 villeins and four soke men; and the manor consisted of about 1000 acres. In 1081, it had a priest, a church, and a mill, of the yearly value of 4s., and ten acres of meadow. In 1858, it has a population of 112,945 souls, engaged in more varied works than, perhaps, those of any other town in the kingdom. Bede, in 735, calls Leeds, Leodys, and the Domesday Survey, Leedes; and Thoresby says it was one of the 28 cities of ancient Britain mentioned by Nennius, and called the city of "Loid in the Wood." The out-townships, as they are called, are said to derive their names:—1st. Hunslet, from "Hunde" a dog, and "Slet" a house, because of the number of dogs which were formerly kept there. Its population is employed in the manufacture of flax, woollens, iron, glass, wire, glue, earthenware, chemicals, locomotive engines, carriages, steam-boilers, and the getting of coal. 2nd. Holbeck derives its name from the Saxon word "Hol," a low place, and "beck," or the brook which flows through it. It is described by a recent historian, as "one of the most crowded, one of the most filthy, one of the most unpleasant, and one of the most unhealthy villages of the county of York." But still, the description which this historian gives is greatly exaggerated. Holbeck is, and Hunslet is nearly now, united to Leeds in unbroken continuity. It possesses a large supply of sulphureous water, once celebrated for medicinal virtues, but now required for and applied to manufacturing purposes. Its population is employed in the manufacture of flax machines, and woollens. 3rd. Bramley.—Its population is mainly employed in the woollen manufacture, agriculture, and the getting of the celebrated Bramley Fall stone of millstone grit. 4th. Wortley, situated about a mile from Leeds, is said to derive its name from its herbage. Armley, from one "Arm" or "Orm," and "ley," a field. 5th. Headingley, from "Hedde" a Dane, "ing," a patronymic added to his fathers, and "ley," a field. Headingley-with-Burley is full of the suburban residences of our merchants and manufacturers; whilst Kirkstall, which forms part of the same township, contains woollen, worsted, and flax factories. There is, just without the borough, and at a short distynce from the Abbey, one of the largest iron forges of the neighbourhood, which in Thoresby's time (1658) was so extensive, that he declared it might serve Vulcan and his Cyclops to work in. The fulling-mills of Armley and Kirkstall are perhaps the most ancient in this part of Yorkshire. 6th. Chapel-Allerton, two miles from Leeds (north), is said to derive its name from four adjoining hamlets, called the Alder hills. It is mainly composed of suburban residences. Its poor population is employed in agriculture and the getting of stone. 7th. Beeston, two miles and a-half from Leeds, though now an agricultural and mining village, was once celebrated for the manufacture of bone, lace, and straw hats. Coal mines have long been worked here, and iron is also now obtained of a peculiarly fine quality. 8th. Farnley, about two miles from Leeds, derives its name from the ferns which formerly grew here in great abundance, and which to this day flourish in many parts of it. Its population is employed in the woollen manufacture, the getting of coal of rather an inferior quality, of clay, particularly for sanitary pipes, and in the manufacture of iron. 9th. Potternewton, about two miles from Leeds (north), is said to derive its name from its being a new town, in which potteries and brick kilns existed, contiguous to a Roman station. It possesses many suburban residences; its industrial population is mainly employed in agriculture and getting of stone. Of the remaining small hamlets within the borough there is not much to be said. Their populations amount to 237, who are mainly employed in iron and coal mines, and in agriculture. For municipal purposes these out-townships are divided into wards, which send representatives to the Borough Council chamber. In the following Table the superficial area in statute acres and the population in each ward are given. Leeds proper is also divided into wards, the superficial area of each of which is also given in statute acres, in order that both within and without the town the density of the population upon the acre may be seen. Thus, for instance, in the out-townships:—

Out-Townships.	Area in acres.	Inhabited Houses.	Population in 1851.	Pop. to a house.	Populn. per acre.
Farnley	1990	350	1722	4·9	0·8
Potternewton	1657	282	1385	4·9	0·8
Chapeltown	2747	612	2842	4·6	1·0
Beeston	1535	427	1973	4·8	1·2
Headingley	3058	1222	5105	4·9	1·9
Bramley	2331	1876	8949	4.7	3·8
Armley	907	1303	6190	4·7	6·7
Wortley	1036	1672	7896	4·7	7·6
Hunslet	1100	4216	19,466	4·6	17·6
Holbeck	760	3099	14,152	4·5	18·6
	17,121	15,059	70,680		

Wards.		LEEDS PROPER.			
North-West	538	2693	12,270	4·5	22·8
East................	657	3781	17,421	4·6	26·5
West	560	4231	20,176	5·0	36·0
North-East	541	4564	21,301	4·6	38·0
Mill-Hill...........	127	969	5414	5·5	42·7
South...............	123	1363	6677	4·9	54·2
Kirkgate	31	632	3377	5·3	107·6
North	92	2828	14,454	5·1	157·1
	2672	21,061	101,090		
Out-townships....	17,121	15,059	70,680		
	19,790	36,120	171,770		
			293 military.		
			172,063		

We thus see that over the whole borough the population to a house varies, so to speak, from 4½ to 5½, the density on the acre being from 0·8 to 157. In all the townships of the borough, with the exception of one (Beeston), and in all the wards of the town proper, with the exception of Kirkgate, this density increased in the decennial period between 1841 and 1851, and it has gone on increasing up to the present period, with the exception of the Mill Hill Ward, in addition to Kirkgate, in which, since 1851, it has also decreased. At the present day the population of Leeds proper is 112,945—of the out-townships, 77,748. The number for Leeds is calculated on the proportion of persons to a house in each ward in 1851, the multiplicand being the number of inhabited houses in July, 1858, correctly ascertained in wards from the rate-books. That for the out-townships is based on the per-centage increase of Leeds proper. The superficial area of the town of Leeds is thus shown to be in the aggregate of the wards 2672 acres and 2 roods, of which, in 1840, 695 acres were occupied by buildings.

Ward.	Land. A.	R.	P.	Buildings. A.	R.	P.	Total. A.	R.	P.
East	546	3	0	111	0	0	657	3	0
North-East	466	0	0	75	3	0	541	3	0
North-West	456	0	0	82	1	0	538	1	0
West..................	384	0	0	176	0	0	560	0	0
South	66	1	0	57	1	0	123	2	0
North	28	1	0	63	3	0	92	0	0
Mill Hill............	26	1	0	101	2	0	127	3	0
Kirkgate...........	4	0	0	27	2	0	1	2	0
	1977	2	0	695	0	0	2672	2	0

The inhabited houses of each ward, with the population and its increase and decrease, stand as follow:—

	1841.		1851.			Per cent. 1858.						
	Hous.	Popul.	Hous.	Popul.	Incrs.	Decr.	Hous.	Incrs.	Decr.	Popul.	Incrs.	Decr.
East......	3436	15,530	3781	17,421	10·3	0	4038	6·7	0	18,570	6·7	0
N. East..	3959	17,887	4564	21,301	19·1	0	5174	13·3	0	23,798	11·6	0
N. West.	2237	10,669	2693	12,270	15·6	0	3441	27·7	0	15,484	26·1	0
West.....	3475	16,616	4231	20,176	21·4	0	4906	15·9	0	24,530	21·5	0
South....	1273	6210	1363	6677	7·5	0	1502	10·2	0	7358	11·6	0
North....	2711	13,001	2828	14,454	11·1	0	2891	2·2	0	15,744	8·9	0
Mill Hill	996	5222	969	5414	3·6	0	940	0	3	5170	0	13·9
Kirkgate	656	3411	632	3337	0	2·2	621	0	1·7	3291	0	1·4
							23,513					

by which we gather, that, of late years, the tide of population in Leeds has steadily flowed towards improved ventilation and surface condition: since the increases in seven years, from 1851 to 1858, in the West and North-west Wards, exceed the per centage decennial increases of the ten years between 1841 and 1851. There has been a gradual decrease in the number of inhabitants in the Mill Hill Ward, which is in the centre of the town, and mainly composed of wide and well-ventilated streets; but here the population has given way to warehouses, shops, and offices. And in the Kirkgate Ward there has also been a continued decrease which we can understand;—for though it is also in the centre of the town, as it were, and mainly occupied by shops and warehouses, yet its dense courts and yards lie contiguous to a river, which, though a trout stream within the last seventy years, having footways clothed with avenues of trees, is now nothing but an open sewer, containing the sewerage of Bradford, Shipley, and all the mills, houses, dyehouses, tanneries, and workshops, which crowd its western banks; and cannot, therefore, be healthy or pleasant to those who have not the means of removing elsewhere. We see, in fact, towards the less densely populated wards, a gradual movement made from the old localities, as well as a steady increase of a new population. Mr. Baker proceeded to exhibit the diminution in the rate of mortality resulting from the sanitary improvements effected by the Local Improvement Act and the Burial Act. In the north districts, for example, in the seven years from 1851 to 1858 the deaths decreased 25 per cent., the population meanwhile increasing in density, and the ratio of births to the population remaining the same. So also in the south-east district, with an increased population, the deaths decreased 16 per cent., and in the west district the mortality diminished 5 per cent. He considered that other ameliorating influences had been at work within the period in question, such as compulsory vaccination, the decrease of cellar occupancies, emigration to better-ventilated districts, improved regulations as to hours of labour, improved wages, temperance societies, a higher social and intellectual state brought about by lectures, cheap publications, and institutes for mutual improvement, all of which remedial elements Leeds possesses in an eminent degree. The importance of sanitary measures at Leeds could scarcely be over-rated, considering that 18 per cent. only of all its houses exceed £10 annual rent—a fact which showed how largely the population was composed of the working classes. Referring to some of the larger trades conducted in the town proper, he mentioned the following as being the staple:—Woollen, worsted, flax, silk, dyeing, machine-making, leather, paper, tobacco, sanitary pipe and fire-brick, glass, earthenware, glue, and chemicals, coal, stone, railway terminals, and making garments for exportation. He doubted whether the prevailing manufacture of Leeds was at the present time woollen, or the fabrication of machinery. The interests engaged in the woollen trade were—the manufacturer, the finisher, and the rag-grinder; and, as illustrative of the condition of this important branch of trade, he introduced these statistics:—

First process.	Firms.	Nominal horse power.	First process, spinning.	Gigs.	Power looms.
1st	68	1936	8640	—	952
2nd	48	860	—	860	—
3rd	12	128	—	—	—
	128	2924	8640	860	952

Total number of persons employed, 10,193.

The wages of these processes are as follows:—

	Annually. £	s.	d.	Weekly. £	s.	d.	Per person weekly. s.	d.
First process, manufacture	110,120	8	0	2117	14	0	11	7
Second, finishing	254,215	0	0	4888	15	0	15	8¾
Third, rags	5760	16	0	110	15	0	6	0¼
Total	£370,096	4	0	7117	4	0	10	0¼

Mr. Baker presented a mass of information relating to other branches of industry carried on to a large extent in the town, and employing 45,829 persons, whose wages he computed at £1,752,689 per annum, or £33,734 a-week. Speaking of the poverty or improvidence of the working population, he said that in 1857 there were relieved out of the rates 2238 men, 4862 women, 5653 children, and 4864 vagrants; in all 17,437 persons supported out of the savings of the industrious, notwithstanding all that was done by charity, by secret orders, and benefit societies. To his mind this pauperism was the result of sheer improvidence, and it would have to be dealt with by social science. He trusted that the day was dawning when morality would be a lesson taught with labour, and when as a people we might be wiser and better for our abundant benefits.

On the Degree of Education of Persons tried at the Middlesex Sessions. *By* JOSEPH BATEMAN, *LL.D., F.R.A.S.*

During the year 1856 there were 1717 persons charged with offences at these Sessions. Of these, 880 (or more than one half) could not write; viz. 379 could not read, and 501 could read but not write. Of these 880 persons who could not write, 579 (out of 1262 committed or bailed, being almost one-half) were males, and 301 (out of 455, being two-thirds) were females. Besides these, 401 were returned as able to read and write imperfectly; viz. 74 males and 27 females. On the other hand, there were 677 out of the 1717 charged (being more than one-third) who were stated to be able to read and write well; viz. 561 males out of 1262 charged, and 116 females out of 455 charged, and 18 (all males) reported to possess a superior education. This amount was so considerable as to give a colour to the opinion which still prevails to some extent, that the imparting of the mere elements of education does not necessarily improve the morals of the people. But there is one circumstance connected with these statistics which is usually overlooked, and which it is the chief object of the present paper to point out:—it is this. Middlesex, to which these returns relate, is a county in which elementary education is more generally diffused than it is throughout the country at large. It appears by the Registrar-General's Report that in 1854 the proportion of men who, in the metropolis, wrote their names in the Marriage Register was 88 out of every 100, and the like proportion of women was 79 out of every 100. It may be inferred therefore that there are in the metropolis only about 12 men in 100, and 21 women in 100 who cannot write; and consequently that the criminals in that part of the country are not taken from the entire community indiscriminately, but that full *one-half of them* are taken from the class of extremely ignorant, consisting of *one-sixth of the population*, thus reducing the criminals among the educated classes to a very small proportion indeed: and, if we confine our observations to the case of women alone, we shall find that the extremely ignorant class, consisting of *one-fifth* only of the whole female population of the county, furnishes *two-thirds* of its female criminals.—See Report of Mr. Pashley, Q.C., to the Middlesex Magistrates.

On the Investments of the Industrial Classes. *By* JOSEPH BATEMAN, *LL.D., F.R.A.S.*

The investments of the industrial classes are chiefly made in Friendly Societies and Savings Banks. The number of friendly societies enrolled and certified, and now in existence in England and Wales, is about 20,000, and the number of members belonging to them exceeds 2,000,000, with funds exceeding £9,000,000, of which the sum of £1,431,543 is in English and Welsh savings banks, and the sum of £1,944,991 invested with the Commissioners for the Reduction of the National Debt, making a total of £3,376,534 so invested. The number of individual depositors in savings banks on the 29th November, 1857, was 1,241,752, and the sum due to them was £32,984,923. It thus appears that the members of these societies and depositors in savings banks possess funds amounting to nearly £42,000,000, and that the average investment of each member of the friendly societies is £4 10*s.*, and of each depositor in the savings bank about £26 11*s.* 3*d.* It appears that the number of depositors in savings banks is five times more than the number of persons entitled to dividends on the public funded debt; and that of those so entitled to dividends, by far the greater number are for very small amounts, such as may be supposed to belong to the humbler classes; whilst the total number of persons receiving dividends exceeding £4000 per annum amounted only in the year 1856 to 227 in the United Kingdom. Another class of investments open to the working classes, but which was too little known to be acted upon, was the purchase of deferred and other annuities of the Commissioners for the Reduction of the National Debt, who were empowered to grant such annuities (not exceeding £30 per annum to one person) on very advantageous terms to the purchaser. The number and value of these annuities purchased up to 5th January, 1857, were—immediate, deferred, and life annuities, number 10,864; purchase-money £2,071,831 18*s.* 11*d.*; for terms of years, number 373; purchase-money £53,081 17*s.* 6*d.* Referring to the antiquity of friendly societies, it was remarked that Mr. Kenrick, the learned author of 'The Roman Sepulchral Inscriptions,' had shown that burial clubs were in existence among the Romans, and he had actually discovered a copy of the rules of such a society inscribed in marble. At the present moment there were more friendly societies of one kind or another in England and Wales than were to be found in the whole of the rest of Europe, or perhaps elsewhere. No less than 26,000 had been established according to law in England and Wales between 1793 and 1857, besides immense numbers of trade societies and "orders," some of them numbering their members by hundreds of thousands, and many of which no account was returned to the Registrar. Of the friendly societies properly so called, and which had come to the knowledge of the Registrar, there were, as has been said, 20,000, by which, in the aggregate, no less a sum than £1,000,000 per annum was expended for affording relief in sickness alone. In the year 1857, the friendly societies in Leeds raised, in round numbers, £25,000, and distributed £20,000. The author proceeded to notice the various other classes of friendly societies and modes of investment for the industrial portion of the population; the recent improvement of the law relating to those institutions; and, as another pleasing fact, the increasing confidence in savings banks, notwithstanding the failure at Rochdale and a few other places; and he expressed a hope that such failures would be prevented in future by the Government taking upon itself the responsibility of the funds. If the savings laid out by the working classes in the various other modes besides benefit societies and savings banks could be ascertained and added to the sums disclosed by the official accounts, they would swell the total to a sum that would astonish some persons by its vastness; and, though he did not think it would prove that the industrious classes were all as thoughtful and prudent as they ought to be, it would show that they were not so thoroughly dissipated and careless as some persons had represented; and they were entitled to every encouragement and assistance in carrying out their habits of prudence and economy.

Trade and Commerce the Auxiliaries of Civilization and Comfort. *By* T. Bazley, *M.P., Manchester.*

Mr. Bazley sketched the rise and progress of the cotton trade, as confirming and supporting the views enunciated in the title of this paper. In 1758 the imports of cotton and its consumption by domestic labour might be three millions of pounds weight for the entire year, but in the present year, a century afterwards, the quantity consumed would be one thousand millions of pounds, of which the United States supplied three-fifths, the other two-fifths being obtained from the East Indies, South America, Egypt, and the West Indies. For the last year, by the return made by the Board of Trade, the exports of cotton manufactures sent to every part of the world amounted to upwards of thirty-nine million pounds sterling. Hence this large sum became the agent of payment to a corresponding extent of imports; but in thus largely aiding in procuring increased supplies of foreign products, whether in gold, silver, raw materials, food, wines, sugar, fruits, or luxuries of distant growth which are received into the United Kingdom, there was the satisfaction that our cotton industry had contributed clothing comforts to the benefit alike of the savage and civilized in every region of the earth. In this current year the exports of cotton manufactures would perhaps amount to forty millions value, and the portion left for home consumption might be twenty millions, or equal to 17*s.* per head for the population of this country; but, as the cotton trade of Great Britain is not half its magnitude in the entire world, including the domestic and semi-domestic manufacture still extensively carried on in the East, the manufacture of the world at large could not be less than the annual value of one hundred and forty millions, and therefore this industry afforded to the world's population 3*s*. worth each of cotton clothing, or, represented in calico, fourteen yards per annum for every man, woman, and child in existence. Presuming the cotton industry of this country to amount to sixty-four millions in value for the current year, and the cost of the raw material to be twenty-four millions, then the sum remaining for wages, interest of capital, rent, taxes, fuel, freight, carriage, and other requisites, would be forty millions. The population employed in this trade exceeds half a million, and, as every worker is said to be connected in his family with three non-workers, who depend upon the single worker for subsistence, two millions of people are therefore supported by it. Engineers, founders, machine-makers, and other auxiliary traders employ vast numbers of well-paid workmen, who are constantly engaged and sustained at the cost of the capital invested in the constructive department of the cotton trade; hence these further sources of support increase the total number of people dependent upon this extraordinary industry. Viewing Lancashire as the chief seat of this industry, if we refer to its population a hundred years ago, we find it to have been about 300,000, whilst now it was 2,300,000, making an increase greatly in excess of any of the old trading and agricultural communities of this or any other country. After noticing the numerous other places in different counties of England and Scotland in which the manufacture of cotton has become the great support of labour, Mr. Bazley proceeded to discuss the question of increasing the supplies of the foreign raw material, and urged the importance of opening up new fields for its cultivation. Africa and Asia could grow more cotton than the most sanguine could contemplate the demand of the whole world would ever require; and to extend its production in those two quarters of the globe would be at the same time to extend civilization and to diffuse the comforts of life. Workpeople, manufacturers, merchants, statesmen, and philanthropists had all the deepest interest in this vital question, which hitherto had been shrouded in almost fatal apathy. At home and abroad the wonder was that the British East and West Indies had not supplied the largest portion of the cotton needed in this country. For much of the unproductiveness of those portions of the British empire misgovernment was responsible. Roused, however, by the salutary influences of public opinion, the legislature of our country had given to the East Indies a new existence. No intermediate spoiler would hereafter prevent the queen and a direct executive from developing the resources of India. An enlightened and just policy applied to every British colony would yield the benefits of an extended commerce, blessing, like charity, those who gave and those who received.

Notes on Self-supporting Dispensaries, with some Statistics of the Coventry Provident Dispensary. By CHARLES H. BRACEBRIDGE.

The statistics of the self-supporting Dispensary at Coventry are offered to this Section as an example of those institutions projected by Mr. H. L. Smith, of Southam, Warwickshire, which, when supported by a sufficient number of members, have been successful. The statistics of that at Northampton are fully as favourable, though not carried over so long a period; this latter having been instituted in 1845, and the former in 1831*. The queen's visit to Warwick gave occasion to the formation of a Central Society for the promulgation of the principle, to whom application might be made for information as to rules, books, and other details, by the possession of which the founders might proceed safely, and without danger of failing in their objects, pro-

* The following are the statistics for 1857 of the Dispensaries at Coventry and Northampton:—

Place.	Members.	Cases Attended.	Midwifery Cases.	Paid for Drugs.	Paid to Medical Men.	Paid by Free Fund.
	No.	No.	No.	£	£	£
Coventry .... (founded 1832)...	4500	2927	48	251	491	749
Northampton......... (founded 1845)...	5429†	14960	222	166	578	751

† In 1851.

COVENTRY PROVIDENT DISPENSARY.—*Twenty-seven Years,* 1831-57. *Statistical Analysis of the Report.*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
							Income.			Expenditure.				
Years beginning 25th March.	Number of New Members, including Col. 3.	Members Admitted when Sick by Payment of 10s. for 3 Months' Attendance.	Cases of Sickness.	Cases Visited at Home, exclusive of Col. 6.	Midwifery Cases.	Deaths.	Subscriptions and Donations. Interest of Funded Property.	Payments of Ordinary (Free) Members.	*Total Income.*	Paid to Medical Officers.	Salaries to Dispenser and Boy. Instruments.	Purchase of House, Rent, Rates, Repairs, &c.	Drugs and Leeches.	*Total Expenditure.*
	No.	No.	No.	No.	No.	No.	£	£	£	£	£	£	£	£
1831......	...	...	1500	...	10	19	329	126	455	81	67	27	46	221
32......	...	...	2437	...	55	30	140	366	506	263	77	31	103	474
33......	...	...	1668	...	52	20	144	401	545	268	73	25	113	479
34......	...	...	1624	778	47	27	118	416	534	287	67	43	89	486
35......	...	...	1500	...	41	17	128	397	525	262	72	27	95	456
1836......	...	...	1610	...	53	28	107	392	499	262	74	22	90	448
37......	...	...	1382	...	31	26	138	339	477	245	72	21	54	392
38......	...	...	1638	...	48	34	88	426	514	287	69	23	99	478
39......	...	...	1921	...	39	39	86	429	515	305	69	24	84	482
40......	...	...	2001	...	51	37	92	437	529	287	61	21	110	479
1841......	...	...	} 3543	...	79	57 {	74	418	492	269	63	245	108	685
42......	...	...					306	384	690	273	61	450	71	855
43......	...	...	1847	...	61	22	121	409	530	266	61	12	81	420
44......	...	...	2128	550	61	39	109	445	554	289	67	15	106	477
45......	...	...	2135	400	67	33	87	451	538	293	64	10	105	472
1846......	...	...	2193	...	50	27	74	435	509	283	61	9	75	428
47......	...	...	2044	...	50	35	78	411	489	270	61	9	76	416
48......	...	...	1878	...	30	35	71	377	448	245	61	12	75	393
49......	...	...	2060	...	...	49	69	348	417	226	62	8	86	382
50......	...	...	1795	...	...	39	62	375	437	252	61	15	74	402
1851......	...	...	1664	...	52	32	72	335	407	223	72	10	79	384
52......	...	...	1788	...	...	28	62	345	407	243	77	8	59	387
53......	930	100	1912	549	28	28	63	431	494	288	71	7	92	458
54......	1104	150	2287	720	35	35	64	510	574	340	79	10	119	548
55......	757	115	2445	816	29	57	66	564	630	376	79	26	133	614
1856......	883	122	2654	643	25	64	64	647	711	431	92	15	132	670
57......	685	134	2927	852	48	53	66	749	815	492	97	10	151	750

Note.—From 1831 to 1852 there were two Surgeons; after that, three Surgeons and one Consulting Physician.
The average number of Free Members on the books is about 3000; it was limited, at first, to 2500; it is now about 4500, many of whom are children.

vided always the one necessity of all insurance against risks, and sufficient numbers, be supplied. This little Society was founded at Warwick in July last (1858), the Lord Lieutenant, the High Sheriff, Lord Warwick, Lord Willoughby, and several magistrates and gentlemen of the county, as well as two or three gentlemen from Coventry and Northampton, being present, and vouching for the working of the Coventry and Northampton Dispensaries for more than twenty years. To this Society the following towns have already applied for information:—Bath, Bradford, Conway, Hereford, Southend, and Tadcaster. It is called the "Society for promoting the principles of Royal Victoria Self-supporting Dispensaries." Honorary Secretary.—H. S. Smith, Esq., Southam; Bankers—Messrs. Greaves, Greenway, and Smith, Warwick. The committee meets at the Warwick Arms, at Warwick.

The advantages to members are, that the Dispensaries are founded on the principle of Provident Insurance. Practice is afforded to medical men, and emulation excited. Many cases, no doubt, are brought under their notice which would otherwise have been neglected, till too late for remedies to be applied; to say nothing of the great facilities afforded by these institutions for obtaining statistics of disease, and of their tendency to promote sanitary improvements.

Clubs can be taken in *en masse*, and cholera cases are attended gratis. The payments to medical men, when divided by the number of cases, appear to be about 1*s.* at Northampton, but are considerably higher, about 3*s.* 4*d.*, at Coventry; the other expenses are salaries to Dispenser and a boy, and the purchase of drugs, leeches, and instruments. The variation arises from calculating attendance on *every child* in one instance, and not in the other. In each case the medical men have divided £750*, [Coventry £1 less, Northampton £1 more,] and are satisfied. The number of visits made at patients' abodes in severe cases is not mentioned.

At Coventry each family selects its medical man for the year; so that it becomes unnecessary to enter every slight case among the children for a proportional division among the medical men at the end of the year.

On the Financial Prospects of British Railways. *By* Samuel Brown, *F.R.G.S., F.S.S.*

Mr. Brown gave a summary of the leading facts showing the extension and present position of the railway system of the country. In doing so he confined himself principally to the reports presented by Captain Galton to the Board of Trade, which reports bring down the information to the end of 1856. He also quoted from a Parliamentary document which has recently appeared, showing that the total amount of capital and loans for railways in the United Kingdom, authorized by Acts of Parliament previous to 31st December, 1857, was £387,051,735, of which £7,732,496 was authorized to be raised by shares and £2,614,316 by loan last year. Previous to the year 1857, £281,114,152 was to be raised by shares and £96,458,773 by loans. On the 31st of December last—

	Capital raised.	Dividend on Interest in 1857.	Per cent.
Ordinary share	£178,624,394	6,391,746	3·579
Preference share............	58,126,627	2,706,157	4·655
Loans.........................	78,406,237	3,240,683	4·133
Total..................	315,157,258	12,338,586	3·915

The companies then retained power to raise £72,194,678 by existing shares, by new shares, and by loans. £283,957,225 was the amount stated to be expended in the construction of railway works. The length of line open for traffic on 31st December last was 9447 miles (2681 miles single and 6356 double lines); 993 miles of railroad were being constructed at the end of the year, and 3554 miles of line were authorized, but not then commenced. The total length of lines for which companies had obtained powers prior to 31st December, 1857, was stated at 13,562. In reference to the important consideration of the relative amount of loans, preference and ordinary share capital, Mr. Brown remarked that it was evident that whatever the state of the money

* Less the sum paid for drugs—at Coventry, £251; Northampton, £166.

market, the lowest rate of interest for the time being would always be upon those investments which afforded the largest margin for the certain payment of the interest and the repayment of the principal at the periods agreed on. Of £308,775,894, which was the total amount of money raised up to the end of 1856 for the construction of railways, £77,359,419, or 25 per cent., formed, in the shape of loans, a first charge on the profits of the companies. At the end of 1857, £78,406,237 out of £315,147,260, or 24·88 per cent., was similarly advanced. The total profits from all railways in 1856 appeared to have been £12,277,712, and the interest upon debentures and loans £3,607,072; thus leaving a margin of £8,670,640, or 70·62 per cent. of net profits, to secure the punctual payment of this interest. Under such circumstances, what could be the cause that the average rate of interest on loans so secured should be as high as 4·66 per cent. in 1856, and that in the most favourable year, 1853, it never fell below an average of 4·14 per cent.? What, again, could be the cause that the rate of interest on these securities had gone on increasing in successive years till 1856, though the rate of interest on ordinary share capital had diminished? In 1857 it was true the rate of interest on this class of securities seemed considerably less, but it was still 4·133 per cent., whilst the rate of dividend on ordinary share capital had increased to 3·579 per cent. Looking at the very large surplus which remained, and the ample security thereby afforded for punctual payment of the interest, there seemed no reason to doubt that such loans should be considered nearly equal to government securities. A suggestion had been recently made that all such bonds and obligations should be made payable to the bearer, and transmissible from hand to hand without expense or trouble. The suggestion was well worthy of notice, and the effect would be, no doubt, to diminish the rate of interest at which such advances were made, and ultimately this class of loans would probably not differ much in value, nor fluctuate much more in market price, than the public funds. A difference of one-half per cent. interest on the existing loans of £78,000,000 would amount to £390,000 per annum—no mean advantage to the ordinary shareholders. Passing to the question of the preference shares, Mr. Brown pointed out that in 1857, if there had been no preference shareholders, but all had shared alike, the average dividend would have been 3·915 per cent. The truth was, that the raising of money, either by debentures or preference shares, was a false system, and always acted prejudicially to the ordinary shareholders, unless their annual dividends amounted to, at least, the same rate per cent. on their capital as they had to give on debentures or preference shares. After remarking upon questions of the reduction of the working expenses of railways, the increase of traffic receipts (which, notwithstanding periods of commercial depression, had made steady progress for several years), Mr. Brown said, in conclusion, that some of the evils from which railway shareholders were now suffering, though recognized, could not be remedied. Mr. Stephenson computed that no less than £14,000,000 had been spent in law proceedings. Yet, for all this, if the loan, preference and ordinary share capital were considered as one interest, the results, though falling far short of the expectations entertained, gave no occasion to despair of the future. A net profit of £12,338,586 in 1857 on a capital paid up of £315,157,258 (share and loan), yielded 3·915 per cent., and was a fair vantage-ground for further progress. With a diminution in the rate of interest when the debenture and preference share capital was better understood, under improved management; with a revision and a reduction in some of the various sources of expenditure; with constantly augmenting traffic receipts; with a cessation of the fatal and senseless competition which had so long prevailed; with a tribunal for arbitration which would save both legal expenses and the reckless opposition of the companies amongst each other; with more regard to the convenience of the public in the arrangement of the trains; with more attention to the comfort of third-class passengers; and with some system to check the construction of unnecessary lines, and to develop the commerce of districts by officials thoroughly versed in the resources they afforded, there could be no reason for railway shareholders to give way to despondency, but rather to look with pride and satisfaction on a branch of commercial enterprise, the capital embarked in which fell little short of £400,000,000 sterling, and of which the net profits on the amount paid up exceeded last year half the interest upon the permanent National Debt.

On the Laws, according to which a Depreciation of the Precious Metals consequent upon an Increase of Supply takes place, considered in connexion with the Recent Gold Discoveries. By Professor CAIRNES.

Prof. Cairnes referred to the discussions occasioned by the recent gold discoveries as exhibiting, on the part of a large number of those who engage in them, a strange unwillingness to recognize, amongst the inevitable consequences of those events, a fall in the value of money. He said a strange unwillingness, because similar doubts were not found to exist in any corresponding case. With respect to all other commodities, it was not denied that whatever facilitated production promoted cheapness, that less would be given for objects when they could be attained with less trouble and sacrifice. It was not denied by any one pretending to economic knowledge that the enlarged production of gold now taking place had a tendency to lower its value; but it seemed to be very generally supposed that the same cause—the increased gold production—had the effect, through its influence on trade, of calling into operation so many tendencies of a contrary nature, that, on the whole, the depreciation must proceed with extreme slowness, the results being dispersed over a period so great as to take from them any practical importance, and that at all events up to the present time no sensible effect upon prices had thence arisen. The existence of this opinion amongst economists was, he apprehended, to be attributed in some degree to the circumstance that so few had taken the pains to compare the actual prices of the present time with those of the period previous to the gold discoveries; but much more to the fact that the character of the new agency and the mode of its operation were not in general correctly conceived. The most general opinion with reference to the action of an increased supply of money upon its value was, that a depreciation of money, so far as it arises from this cause, is uniform, that is to say, takes place in the same degree in relation to all commodities; and that therefore prices, so far as they are influenced by an increase of money, must exhibit a uniform advance; and, no such uniformity being observed in the actual movements of prices, the inference had not unnaturally been made, that the enhancement, so far as it has taken place, is not due to this cause—that it is not money which has fallen, but commodities which have risen in value. With respect to this doctrine of the uniform action of an increased supply of money upon its value in relation to commodities, he was quite prepared to admit its soundness, provided sufficient time were allowed for the disturbances introduced by the new additions to be corrected. He conceived, however, that these disturbances, when the augmentations took place upon the scale which we were at present witnessing, were of a kind which did not admit of speedy correction, but might continue throughout the whole period of progressive depreciation; a period, which, if he might venture to express an opinion on the subject, would probably extend over some thirty or forty years. The mode in which an increased production of gold operated in depreciating its value, and thus raising general prices, appeared to him to be twofold, and to take place, first, directly, through the medium of an enlarged money demand; and secondly, indirectly, through a contraction of supply. Prof. Cairnes then stated in detail the considerations from which he arrived at the following general conclusions:—First, that the commodities, the price of which may first be expected to rise under the influence of the new money, are those which fall most extensively within the consumption of the productive classes, but more particularly within the consumption of the labouring and artisan section of these. Secondly, that of such commodities, that portion which consists of finished manufactures, though their price may in the first instance be rapidly raised, cannot continue long in advance of the general level, owing to the facilities available for rapidly extending the supply; whereas, should the production, from over-estimation of the increasing requirements, be once carried to excess, their price, in consequence of the difficulty of contracting the supply, may be kept for some considerable time below the general level. Thirdly, that such raw products as fall within the consumption of the classes indicated, not being susceptible of the same rapid extension as manufactures, may continue for some time in advance of the general movement, and that among raw products the effects will be more marked in those derived from the animal than in those derived from the vegetable kingdom. And, fourthly, that the commodities last to feel the effects of the new money, and which may be expected to rise most slowly under its influence, are those articles of finished manufacture which do not happen to fall within the range of the new expenditure; such articles being affected only by its indirect action, that is to say, through its action upon wages, and this action being in their case obstructed by the impediments to the contraction of supply. Up to this point, Prof. Cairnes said, he found his conclusions corroborated by the independent investigations of an eminent French economist, M. Levasseur. There was, however, another principle which it appeared to him must exercise a powerful influence on the course of the movement, namely, that efficacy which resides in the currency of each country into which any portion of the new money may be received for determining the effect of this infusion on the range of local prices, using the words "local prices" with reference to commodities in the locality in which they are produced, not to that in which they are sold. According to this principle, the advance followed the locality in which the commodity was produced. Thus the rise in price had been most rapid in commodities produced in the gold countries, having in these at one bound reached its utmost limit—that, namely, which is set by the cost of producing gold. After the commodities produced in the gold regions, the advance, he conceived, would proceed most rapidly in the productions of England and the United States; after these, at no great interval, in the productions of the Continent of Europe; while the commodities the last to feel the effects of the new money, and which would advance most slowly under its influence, were the productions of India and China, and, he might add, of tropical countries generally, so far as their economic conditions correspond with those of these countries. Prof. Cairnes submitted to the Section some statistical tables which he had drawn up, with a view to compare the conclusions at which he had arrived as to a depreciation of the precious metals under the action of an increased supply with the actual progress of prices up to the present time. He remarked that, considering the propitiousness of the seasons, the action of free trade, the absence of war, the contraction of credit, and the general tendencies to a reduction of cost proceeding from the progress of knowledge, were there no other cause in operation, we should have reason to look for a very considerable fall of prices at the present time, as compared with, say eight or ten years ago. Prices, however, had very decidedly risen, and the advance had, moreover, proceeded in conformity with the principles which he had in his paper endeavoured to establish. This was his ground for asserting that the depreciation of our standard money was already, under the action of new gold, an accomplished fact.

On the Progress of the Principle of Open Competitive Examinations. By EDWIN CHADWICK.

On the Registry of Deeds in the West Riding. By J. E. DIBB.

The West-Riding Registry, he stated, was established on the 29th of September, 1704, the first object being to facilitate the borrowing of money by honest traders, who found it difficult to give security to the satisfaction of the money-lenders, although the securities they offered were really good. The second object was, to remedy the evils which might be produced by secret conveyances of freehold property, by means of which the ill-disposed had it in their power to commit fraud. That registry which the law thus permitted had, for a long series of years, become the ordinary practice; and it would, perhaps, scarcely be possible at this time to find a freehold estate in the West Riding which is not affected by a registered document. Passing by 1704 to 1710 as exceptional, it might be noted that while the yearly average of the registries from 1711 to 1720 was only 838, the average from 1791 to 1800 had risen to 2355; and taking the average from 1841 to 1850, it rose to 5138, having more than doubled itself in the first half of this century. This increase of transactions in landed property was nearly in proportion to the increase in the population of the West Riding, which was, in 1801, 572,168; 1811, 662,875; 1821, 809,363; 1831, 984,609; 1841, 1,163,580; 1851, 1,325,495. In 1851, however, the gradual increase of previous years was changed for a much more rapid rise; far greater in proportion than the increase of the population. The previous year, 1850, had shown the largest number of deeds registered, viz. 5950; the year 1851, however, reached 8009, and, in 1853, the largest number of all was attained, viz. 9910. This large accession of transactions in real estate at this period arose, Mr. Dibb stated, from the fact that in October 1850, the new Stamp Act came into operation, by which the duties payable on conveyances and mortgages were very largely reduced. Beginning with the year 1843, the operations of building societies have gradually assumed some importance. The number of deeds registered in connexion with these societies had risen from 31 in the year 1843, to 637 in 1857, the largest number being 682 in 1855. The total for the last fifteen years was 4608. A system of registry which enabled a vendor or mortgagor to show readily that he had a satisfactory title, and which secured the purchaser or mortgagee against secret and fraudulent conveyances, must be a benefit, provided the cost of its attainment be not too great. The distinctive feature of the West Riding Registry was, that while anyone might search and inspect its records, there was, nevertheless, no exposure of private affairs. In conclusion, Mr. Dibb suggested that a consideration of the statistics of the West Riding Register would afford many very useful suggestions towards the establishment of a general register, as well in those particulars which it might be desirable to adopt, as in those which it might be prudent to avoid.

Mr. Donnelly, Registrar-General of Ireland, gave an account of the manner in which agricultural statistics are collected in that country. About 4000 enumerators, selected from the constabulary force for their intelligence, were employed last year. The names of all occupiers, nearly 600,000, are obtained, and, so far as could be ascertained, not a single tenant farmer, however small his holding, refused to give the required information. This success he attributed mainly to the assistance afforded by the landed proprietors, magistracy, and clergy of all denominations, and by the press, in removing prejudices against these inquiries; but particularly to the gratuitous distribution, annually, of about 10,000 copies of 'General Abstracts*,' which show, by counties, the number of live stock, and the acreage under each crop, all reference to the property of any individual being carefully avoided. Tables of the estimated produce of the various crops, and of the size of the holdings, in nine classes, by baronies, and Poor Law Unions, are also subsequently published, so that these statistics are becoming more perfect each year, and are now very popular in Ireland.

On Public Service, Academic, and Teachers' Examinations. *By* James Heywood, *F.R.S.*

English public service examinations are of two kinds; comprising a special adaptation to the business of each respective office in the case of candidates nominated by private influence; and a more general range of examination, so as to admit candidates from public schools or the ancient universities, in the case of competitive examinations, without nomination.

For the civil service of the Government at home, a nomination by private influence is the first requisite; candidates thus obtain a place on the list for examination in the department to which they desire to belong; the examinations vary according to the requirements of the different offices of state, and are frequently special.

Under the Committee of Council of Education, the preliminary examination for clerkships includes, writing from dictation, arithmetic, bookkeeping, the précis and digest of forms into summaries, making fair copies from rough notes, and the calculation of per-centages.

A competitive examination follows, which comprises English composition, geography, history, mathematics, and natural science.

The organization of competitive examinations for the Royal Military Academy, Woolwich, was carried into effect with the aid of the Right Hon. W. Monsell, M.P., Sir Benjamin Hawes, and the Rev. H. Moseley. Age in the candidates is limited to between seventeen and twenty years; a certificate of good character is required from each candidate, and an inspection by military surgeons is ordered, to prove the bodily fitness of the candidates for the performance of military duties. No nomination is requisite, but the examination is conducted on the basis of the general education of the country, and is intended to admit the competition of candidates educated in the public schools, so that candidates for the Royal Artillery and Royal Engineers may have secured the acknowledged advantages of the training of these schools, which are connected quite as much with the large open play-grounds, and bold athletic games

* These Abstracts cost One Penny each.

of the boys, as with the scholastic system, in which the number of masters does not always suffice for the complete superintendence of daily instruction.

Of the thirty young men who were selected in June 1857, for the Woolwich Academy, ten had been educated in the University of Dublin, one was a member of Merton College, Oxford, one came from Rugby School, two from Marlborough College, one from King's College School, London, one from Ipswich School, one from Cheltenham College, one from Kensington Proprietary School, one from Clapham Grammar School, and the remaining eleven had been educated privately.

Candidates for the Indian civil service are required to be between the ages of eighteen and twenty-three; and a medical certificate of the absence of any physical infirmity, with a satisfactory testimonial of good moral character, is the principal introduction requisite to admit a candidate to the examination for entrance. The business of regulating the examination has been entrusted to the Civil Service Commissioners, the Right Hon. Sir Edward Ryan, and Sir John Shaw Lefevre, whose central office is at Dean's Yard, near Westminster Abbey; in the month of July, in the present year 1858, the candidates were examined in the large rooms of Burlington House, Piccadilly, London. Sixty-five candidates were arranged in order of merit after this examination, of whom the first twenty were appointed to the Indian civil service. An Irish newspaper-writer, on looking over the list, noticed at once that the largest number of successful candidates had come from classical Oxford, nine out of the twenty having been Oxonians; six successful candidates were members of the University of Dublin, and of these, five were holders of classical scholarships in Trinity College. Altogether, of the twenty who succeeded, there were sixteen classical men elected to the Indian civil service.

Two memorials have been recently presented to the Senate of the University of London, from various eminent scientific gentlemen, requesting that degrees in science may be conferred in that university. A committee of the Senate, consisting of the chancellor (Earl Granville), the vice-chancellor (Sir John Shaw Lefevre), Dr. Arnott, Mr. Brande, Sir James Clark, Dr. Faraday, Mr. Grote, and Mr. Walker, was consequently appointed to consider the propriety of establishing a degree or degrees in science, and the conditions on which such degree or degrees should be conferred.

Many of the memoralists have kindly contributed evidence on scientific degrees to the committee, and the preliminary report of the committee recommends the constitution of one or more degrees expressly attesting scientific proficiency and eminence.

A considerable number of training colleges for the education of schoolmasters and schoolmistresses have been established under the Committee of Council in connexion with different religious denominations, and to these institutions, between the years 1837 and 1857 inclusive, the Committee of Council awarded grants amounting altogether to £347,000.

Many of the English Normal Schools are connected with the Church of England, but the plan of instruction includes a variety of subjects equally valuable and interesting to the members of all religious denominations.

The training institution for teachers, in connexion with the British and Foreign School Society in the Borough Road, Southwark, has outgrown the accommodation afforded by the original design. Mr. Bowstead, in his report on this institution, dated January 1858, observes, that "several candidates who successfully passed the recent examination for Queen's scholarships have been unable to obtain admittance."

On the Importance of a Colonial Penny Postage, viewed in relation to the advancement of Science and Christian Civilization. By Mrs. Wm. Fison.

Beneficial influence of the Penny Postage.—If the history of the penny postage in this country were investigated, it would be found to have been a most important promoter of scientific progress, of education, commerce, religion, and the principles of good government.

To the poorer classes its benefits have been incalculable in stimulating them to acquire the power of writing.

When the penny postage was first given to this country, many were the fears expressed as to the result, none of which have been realized; and its extension to the colonies is now advocated on grounds of high importance.

In a religious and moral point of view, the benefits of a colonial penny postage would be inconceivably great to our fellow-countrymen in the colonies. It must be remembered that the tide of emigration is rolling on at a rate that exceeds every ecclesiastical resource, and baffles every endeavour adequately to influence it by ordinary means of evangelization.

The important measure now advocated would prove one great means of remedy for these evils. It would penetrate to the most remote districts of our colonies, entering the scattered dwellings of emigrants, too far removed perhaps from civilized life for any other outward medium of religious and intellectual progress.

Another most important consideration in favour of a colonial penny postage, is the influence it would exercise upon emigration.

From the increase of education in Great Britain, emigration has assumed a new feature within the last ten or twelve years, and a much larger proportion of the emigrants can read and write.

Nothing is more needed for the full development of this important means of colonization than free interchange of thought between those who have emigrated and friends at home.

In this way would a penny postage be constantly pouring correct and unbiassed information into the mother country, preventing many mistakes made by persons emigrating to the wrong place and at the wrong time, thus avoiding much misery and suffering.

Free correspondence would form a cord binding the colonies to the mother country in ties scarcely possible to dissolve. The effect of distance would be practically annihilated, while the character of the colonists would continue to improve.

In the prosecution of scientific research unrestricted communication between men of science is an important condition of progress. Observers at meteorological, magnetic or astronomical stations, will often have occasion to communicate with others similarly engaged, and it is much to be desired that all such intercourse should be promoted by every possible means.

Nor should the claims of commerce be forgotten in the enumeration of the considerations which favour a colonial penny postage. Let it be remembered that the benefits of free trade can by no means be considered as fully enjoyed while there is any thing like a heavy charge of postage.

It would be difficult duly to estimate the bearing a penny postage to Canada would have upon our Anglo-Saxon brethren in America.

Its action upon the United States would be immediate and powerful, and most probably would quickly induce them to arrange a similar rate of postage to England.

Who can calculate the beneficial results to the human race of such an intercourse between the two great Protestant nations of the world, both sprung from one parent stock, and destined probably to be again united in carrying out the designs of an overruling Providence for the Christian civilization of the world?

On the Causes of the Fall in Price of Manufactured Cottons. *By* J. Pope Hennessy, *M.P., of the Inner Temple.*

The author commenced by observing that, apart from its practical importance to men of business, the accurate determination of the causes which regulate the price of cotton is a subject of much interest to the student of political economy. On that accurate determination must to a great extent depend, in the present state of the science, the value we attach to the arguments of the modern school of British economists with reference to one of their fundamental principles. Mr. Stuart Mill regards the principle in question as the most important in political economy. He states it thus:—The law of production from the soil is a law of diminishing return in proportion to the increased application of labour and capital; whilst in manufactures the very contrary is the case. Mr. Nassau Senior is still more explicit. He says:—Additional labour and capital when employed in manufactures are *more*, when employed in agriculture are *less*, efficient in proportion. At a former meeting of the British Association, Mr. Hennessy pointed out that this principle was not sound in theory. He now proceeded to deal with the great practical illustration—the price of cotton—with which it had been invariably supported. He quoted the principal writers of the modern school; and called particular attention to the following passage from Mr. Senior's 'Elements of Political-Economy':—"A century ago," says Mr. Senior, "the average annual import of cotton wool into Great Britain was about 1,200,000 lbs. The amount now annually manufactured in Great Britain exceeds 240,000,000 lbs. But, though the materials now manufactured are increased at least 200 times, it is obvious that the labour necessary to manufacture them has not increased 200 times. The whole number of families in Great Britain, exclusively of those employed in agriculture, amounted, at the enumeration in 1831, to 2,453,041. If we suppose the transport, manufacture and sale of cotton to employ about one-eighth of them, or about 300,000 families, it is a large allowance. But with the inefficient machinery in use a century ago, the annual manufacture of 1,200,000 lbs. of cotton could not have required the annual labour of less than 10,000 families. It probably required many more. The result has been that, although we now require 200 times as much of the raw material as was required a century ago, and although that additional quantity of raw material is probably obtained from the soil by more than 200 times the labour that was necessary to obtain the smaller quantity, yet, in consequence of the diminution of the labour necessary to manufacture a given amount, the price of the manufactured commodity (a price which exhibits the sum of the labour necessary both for obtaining the materials and working them up) has constantly diminished. In 1786, when our annual import was about 20,000,000 lbs. of cotton wool, the price of the yarn denominated 100 was 38*s.* a pound. In 1792, when the import amounted to 34,000,000 lbs., the price of the same yarn was 16*s.* the pound. In 1806, when the import amounted to 60,000,000 lbs., the price of the yarn had fallen to 7*s.* 2*d.* a pound; and, with the increased quantity manufactured, it has now (1845) fallen below 3*s.* a pound. Every increase in the quantity manufactured has been accompanied by improvements in machinery and an increased division of labour, and their effects have much more than balanced any increase which may have taken place in the proportionate labour necessary to produce the raw material." Mr. Hennessy remarked that any one acquainted with the history of the cotton manufacture of Great Britain would at once see a fallacy which somewhat damages Mr. Senior's illustration. The yarn No. 100, though it had the same denomination, was not of the same quality from 1786 to 1845. With the increase in the production there was a diminution in the fineness of the yarn. This appears to have been owing to popular caprice, and not to any defect inherent in the process of manufacture. The people did not care to get the yarn so fine, and accordingly it was not so expensively manufactured. But there is another fallacy in this statement, which is far more important. During all the periods specified by Mr. Senior there was a continuous fall, instead of a rise, in the price of raw cotton. The extent of this may be judged from the fact, that from 1786, when 19,475,020 lbs. were imported, to 1845, when the annual import was 721,979,953 lbs., the fall in the price of the agricultural product was over 9·33 per cent. From 1806 to 1845—another of the periods selected by Mr. Senior—the fall in the price of the raw material was 4·78 per cent. The precise nature and value of Mr. Senior's mistake will be seen by taking a particular case, and going somewhat deeper into statistics than he has done. In 1812, 63,026,936 lbs. of raw cotton were imported, and the price of the manufactured yarn No. 100 was 5*s.* 2*d.* a-pound. In 1830, when the annual import was 263,961,452 lbs., the price of the same sort of yarn was 3*s.* 4¼*d.*—that is, there was a fall in price of 1*s.* 9¾*d.* According to Mr. Senior, this was owing to the extension of the manufacture—an extension which more than balanced, he says, the rise in price consequent on the increased production of the raw material. A table in Mr. Baines's work, on the 'History of the Cotton Trade,' shows that this difference in price was made up of two items. One of these was the result of the skill consequent, if Mr. Senior must have it so, on the increased manufacture. But this, instead of being more than 1*s.* 9¾*d.*, was only 7½*d.*, and the other amounted to 1*s.* 2¼*d.* Now it appears that this other item, 70 per cent. of the reduced price of the manufactured goods, was solely owing to the reduction in the price of the raw produce, though the amount of that produce had increased 400 per cent.

On some of the Results of the Society of Arts' Examinations. *By* JOHN POPE HENNESSY, *M.P., of the Inner Temple, London.*

Statistics of an interesting and useful kind have at various times been published with reference to the primary education of the working classes. Such statistical tables, however, referred to the period of school life; to the number of years spent at school and the age at which children left school. The results of the Society of Arts' examination furnish a new class of educational facts. They deal with persons who have left the school for the workshop. They enable us to estimate the relative effects of different periods of school-life. They enable us to estimate the effect which early removal from school has on that portion of the working population with which the system deals. In one of the printed forms of inquiry which each candidate at the final portion of the late examination was requested to fill up, the following questions were asked: "How many years were you at school?" "How many years have elapsed since you left school?" The total number of candidates examined this year was 1107, but, as some were rejected at the preliminary examination, as others did not offer themselves for the final examination, and as some of the forms, as far as the mere educational statistics were concerned, were imperfectly filled, not more than 310 supplied the requisite information. I have to thank the Council of the Society of Arts for having placed at my disposal all the documents referring to the examination. Neither the Council, however, nor any of the officers of the Society are answerable either for the statements of fact or the expressions of opinion which this paper contains. The first result at which I arrived was that the average period of the school life of the candidates was under that usually regarded by educationists as the normal and necessary period. Some of Her Majesty's Inspectors of Schools have asserted that the normal period of school life is 12 years. Other educationists have estimated this period at nine or ten years; that being in fact the average duration of school life on the Continent,—in Bavaria, Holland, Switzerland, Sweden, and many other countries. It will be seen from the following table that the great majority of the candidates were at school for a much shorter period.

Under 1 year at school	13	9 years at school	21
1 year at school	12	10 " "	18
2 years at school	11	11 " "	1
3 " "	22	12 " "	7
4 " "	32	13 " "	0
5 " "	49	14 " "	1
6 " "	47		
7 " "	46		310
8 " "	40		

The average period was therefore 6·016 years, or less than 6 years and 6 days. Although this period is much less than that which we are told should be the minimum duration of school life, nevertheless it is somewhat over the average in this country. Mr. Horace Mann proves that the average school-time of all the children in England and Wales is, as nearly as possible, 5 years. I have found, contrary to a common opinion, that in this apparently too short period much benefit is acquired by the pupils. Taking all the candidates who only attended at school for 5 years, 4 years, 3 years, 2 years, 1 year, or less than one year, and calling them Class I.; and taking all the candidates who attended school for 6, 7, 8, 9, 10, 11, 12, and 14 years, and calling them Class II., I find that 129 candidates belong to Class I., and that 181 candidates are included in Class II. These candidates were each examined in a certain number of subjects, chosen from a specified list of 25 different branches of science and literature. There were therefore 25 candidates who obtained highest places; and 14 of these 25 were awarded first prizes. I find that the highest places in fifteen subjects were obtained by the candidates in Class I.—that is, those who had attended school only 5 years, or under, carried off two-thirds of the first places. Of the fourteen first prizes, eight were taken by candidates in the first class; and only six were left for those who had spent six years or more at school. In estimating the practical value of this result, it is necessary to remember that Class I. was numerically smaller than Class II.; the two classes being in the proportion of seven to ten. It therefore appears that, in proportion to the number of candidates in each class, those whose average period of school life was only 3 years 7 months, obtained more than twice as many of the highest places as those whose average school time was 7 years 8 months. Although this result is a fact, and, as such, is probably worth volumes of speculations on the theoretical aspect of the question, yet I do not think it can justify any positive conclusion of much value. Should it be confirmed by the experience of future years, and by a still more widely-extended inquiry, it may become a question whether institutional education—to which, as a matter of course, it is almost altogether owing—ought not to be regarded as a system of popular instruction coming as fairly within the scope of Parliamentary support as the elementary education in the schools under inspection. Without, however, at present justifying a positive conclusion of any great importance, it indicates the necessity of extreme caution in discussing the education question. It would appear to show, for instance, that no fair analogy exists between the school-period of a country like England, where Mechanics' Institutions are established in every town, and countries like most of those on the Continent, where such institutions are not to be found. It would appear to show that youthful labour and early intercourse with the world may enlarge the mind and give additional force to intellectual exertion; and it would even appear to throw a doubt over all schemes —whether compulsory enactments or prize schemes—by which children would be kept at school and prevented from proceeding to work.

The average duration of the candidates' school-life, in various parts of the country, is exhibited in the following table. In the districts marked with an asterisk special prizes were awarded to Local Boards of Examiners and Institutions, in addition to those given to the candidates:—

Name of District.	Average School-period.
*Banbury	5 years 9 months.
Berkhampstead	6 „ 9 „
Blackburn	4 „ 0 „
Bradford	4 „ 3 „
Brighton	8 „ 0 „
*Bristol	6 „ 8 „
Halifax	5 „ 0 „
Ipswich	6 „ 8 „
*Leeds	5 „ 10 „
Liverpool	6 „ 2 „
*Eastern District of London	6 „ 2 „
Western District of London	7 „ 6 „
Louth	6 „ 3 „
Macclesfield	5 „ 0 „
Manchester	5 „ 8 „
Oldham	6 „ 6 „
*Portsmouth (Portsea)	4 „ 3 „
Selby	7 „ 8 „
*Sheffield	5 „ 6 „
Stockport	4 „ 6 „
Wakefield	6 „ 6 „
Wigan	5 „ 8 „
York	7 „ 3 „

Mineral Produce of Yorkshire in 1857.
By Robert Hunt, *F.R.S.*, *Keeper of Mining Records.*

The produce of the lead mines had been 12,405 tons 19 cwt. of lead ore and 7875 tons 12 cwt. of lead, being an increase of 231 tons 12 cwt. on the ore, and a decrease on the quantity of lead produced of 1110 tons 10 cwt., as compared with the year 1856, proving that the ores raised were less metalliferous than in the previous year. Of iron ore the remarkable district of the North Riding yielded 1,414,155 tons in 1857, showing an increase of 216,738 tons as compared with the preceding year. The quantity of clay ironstone raised in the West Riding, as far as returns had been obtained, was 207,500 tons. The cold-blast furnaces of the West Riding appeared to have produced 63,000 tons of pig iron. The total produce of pig iron of the West Riding was estimated at 117,000 tons; the North Riding, 179,838 tons; the total produce of pig iron in Yorkshire being 296,838 tons, against 275,600 tons in 1856. The production of coals from the different districts of the West Riding, in which there are 374 collieries, had been 8,875,440 tons, showing a falling off of 208,185 tons as compared with 1856, in which year the coal production of the West Riding amounted to 9,083,625 tons. From returns received from 102 quarries in Yorkshire, producing stone of various kinds, the value of the stone raised in 1857 was estimated at £105,374. Adopting the market value of the metals raised, and making this addition to the sum, the following would represent the amount added to our national wealth last year by the mining and metallurgical industries of Yorkshire:—Lead, £173,250; pig iron, £1,013,142; iron pyrites, £1572; coals, £2,168,860; stone, £105,374: making a total of £3,462,198.

On the Worsted Manufactures of Yorkshire. By JOHN JAMES, *F.S.A.*

The worsted manufacture was originally established in Yorkshire from two causes —1st, The high rate of wages at Norwich, which led to the employment of the weavers of the West Riding in producing the coarser kinds of worsted, such as shalloons, towards the close of the seventeenth century; 2nd, the introduction of the factory system at Bradford, about the year 1800, when it was neglected by the manufacturers of Norwich, whereby, after a time, one by one of its staple fabrics was transferred to the North. The author referred to the care with which the worsted manufacturers had improved their machinery, so that where formerly 250 revolutions of the cylinder a minute were considered a fair velocity in spinning frames, now 360 is about the number. Likewise the quantity of work from power-looms is very much greater than some time ago, being now 160 to 180 picks a minute, whereas sixty and eighty were not long since the ordinary speed. The consequence of this excellence and velocity of machinery had resulted in the production of worsted pieces of good quality at exceedingly low rates. A mighty revolution had been effected in the worsted industry by the use of cotton warps. In this branch (the worsted) there have been four great epochs; 1st, the original use of spinning machinery; 2nd, the application of the power-loom to the weaving of stuffs about 1824; 3rd, the use of cotton warps in 1835; and lastly, the combing of wool by machines. Mr. James referred at length to the changes that had been effected in the trade by the use of cotton warps. He noticed the defects in the designs of the worsted manufacturers, and their tendency to pirate those of their neighbours; and, after paying a high compliment to the worsted dyers, and noticing the difficulties they had surmounted in dyeing goods woven of cotton and wool, he alluded to the taste for alpaca and lustrous stuffs, and the great demand for the bright lustre wools of Yorkshire, Notts, and Lincolnshire. He proceeded to remark on the limited supply of wool and the competition of the Belgians and French in our wool markets, whereby the price and supply had been affected,—but the quantity exported, and the extra consumption of our manufacturers would, he thought, be more than compensated by the increased import from our Colonial possessions, whence the supply was yearly increasing. Nor did he fear the rivalry of the Belgian and French manufacturers in the markets of the world, for, although we might lose them as customers, they were not heavy ones, and China and other channels would be opened, so that the balance would still be in our favour. These nations were importing vast quantities of spinning and weaving machinery from the best makers at Bradford and Keighley; but with all their efforts it would be long before they could compete with us in producing an Orleans or Coburg cloth at English prices. Yet it behoved us to be watchful lest from the high price of labour in England they tread too closely on our footsteps. To show the immense importance of the Yorkshire manufacture, he mentioned that there were 1,212,587 worsted spindles, consuming 93,120,740 lbs. of wool, or about 93 per cent. of that consumed in the whole of the worsted manufacture of England. These Yorkshire spindles would produce yearly 70,734,000 lbs. of worsted yarns of average quality, say thirty-sixes, that is where thirty-six hanks make the lb. The number of persons employed in the worsted factories of Yorkshire were 78,994, namely 26,750 males, and 52,244 females. Within the last few years the worsted industry had attained the proud position of being the second of the textile manufactures of the kingdom, ranking after that of cotton; but in Yorkshire it was predominant. There the cotton branch was insignificant, and that of woollen only employs in its factories 42,982 persons. In the worsted trade of Yorkshire there are 35,298 power-looms, and in woollen only 6275. Mr. James objected to any estimate which would raise the woollen manufacture above that of worsted in value; and claimed for Bradford the high honour of being the metropolis of the second manufacture in the kingdom. He alluded to the present tendency to employ adult labour in worsted factories. Formerly one-fourth of the factory hands were children; now the proportion is one-eighth. Notwithstanding the panic of last year, which caused such disastrous effects in the worsted districts of the North, and paralysed its trade, it had wonderfully recovered from the shock, and, like a sick man who in a fever had thrown off his morbific humours, now appeared to be in a sound and healthy state. He estimated the whole of the worsted manufactures of England to be of the yearly value (inclusive of materials) of £18,000,000. Of this, the Yorkshire portion is at least £13,000,000, made up thus:—

Worsted pieces of all descriptions	£10,000,000
Yarns—for export, and for the Glasgow, Manchester, Norwich, and other markets	3,000,000

Mr. James spoke highly of the worsted operatives, whom he described as superior in condition to those in any other manufacture, whether physically, morally, or intellectually. The worsted factory girls were, he thought, much superior in cleanliness and appearance, and orderly habits, to those in cotton factories; he remarked on the elegance and respectability of their attire on Sundays, and concluded by expressing an opinion that the worsted manufacture was destined to furnish a large portion of female dress for the whole of the civilized globe, suitable alike for all climes, whether cold or hot, and for all classes, whether grave or gay.

On the Iron Trade of Leeds.

By JAMES KITSON, *jun., of Monk Bridge Iron Works, Leeds.*

The iron trade of Leeds is at once the most ancient and most modern of the branches of industry carried on in the borough; the most ancient, because it can be proved, by the remains of the scoriæ of ancient iron works, that this metal was manufactured here hundreds of years ago; the most modern, as it has attained its present extent within the last thirty years, before which time it existed on a very limited scale.

Extensive beds of scoriæ and other remains have been found at Horsforth, within the borough, and near to the old Roman town at Adel. Four branches of the iron trade flourish in Leeds; the manufacture of—1. Iron; 2. Cut Nails; 3. Textile machinery and machine tools; 4. Locomotive engines and railway plant generally.

1. There are six smelting furnaces manufacturing iron on the cold-blast system, for the production of the highest qualities of Yorkshire iron. Four were in blast last year, which made 12,745 tons of pig iron. The hands employed in this branch are 2120. The average amount of weekly wages £2540. Total wages paid during 1857, £132,080. Total consumption of coals, 198,122 tons. Total production of malleable iron, 41,734 tons. Average price of pig iron sold, £5 1*s.*; total annual value, £30,426. Average price of malleable iron, £15 4*s.*; total annual value, £634,356. Capital vested in plant, buildings, &c. £348,500.

The average price of the malleable iron is double that of ordinary Staffordshire iron, which is a sure indication of the esteem in which it is held; it is used principally for the highest engineering purposes.

2. Cut nails are manufactured extensively. The number of hands employed in this branch is 188. Total wages paid in 1857, £6188. Total production of nails, 3452 tons. Average price, £14 13*s.* Total annual value, £50,575. For those curious in numbers, it has been calculated that about seventy millions of nails are cut in Leeds every week.

3. Fenton, Murray and Co. were the founders of the machine trade in Leeds;

they commenced in 1798, and constructed engines and flax machinery for the mills in the neighbourhood. Machine tools for engineers and others are also extensively manufactured here. The number of hands employed in the trade is 4578. Average amount of weekly wages, £3961. Total amount paid in 1857, £205,972. Total consumption of pig iron in foundries, 13,924 tons. Total value of products, £545,217. Capital invested in plant and buildings, £346,475.

4. Stationary and locomotive engines, wheels and axles, railway bridges, &c., have been largely manufactured here of late. The number of hands employed in this trade is 4023. Average amount of weekly wages, £4151. Total amount paid in 1857, £215,852. Total consumption of pig iron in foundries, 12,862 tons. Total value of products, £672,600. Capital invested in plant, buildings, &c., £283,500. In addition to these, we have about 3000 miners engaged in raising iron-stone and coal for iron manufacturing at an average of £1 per head per week.

The totals of all the four branches are—hands employed, 10,909. Weekly wages, £10,771. Paid in 1857, £560,092. Value of products, £1,933,174. Capital invested in plant, &c. £990,975. The total consumption of pig iron in the forges and foundries of the district is about 75,000 tons annually, or nearly one-third of the annual production of Great Britain only fifty years ago. The greater portion of the goods manufactured is exported to foreign countries. Leeds iron is sent to all quarters and countries of the globe; with Leeds nails the emigrant fastens together his first rude habitation; Leeds machinery is spinning and Leeds tools are working in every seat of industry on the Continent; and Leeds locomotives are drawing their burdens, indifferent whether it be on the fertile plains of India, or on the sides of the snowy Andes. The central position of Leeds, abundance of labour, cheapness of fuel, facility of access to the sources of the raw material, and easy transit to the ports on the east or west coast, are the principal causes of the flourishing state of the iron trade in this town. A branch of commerce which has extended so rapidly, and fixed so large a capital in the town, must contain within itself sound and permanent elements, and the fact that nearly one million sterling is actually invested so as to be practically immoveable is a guarantee that it will be followed with continued energy.

On Free Trade in Belgium. By M. Corranader Mæren, *of Brussels, Chairman of the International Free Trade Association.*

In Belgium, the Government was looking forward anxiously to the reform of the tariff, and a new law had been proposed to reduce the duties on cotton 12 or 15 per cent. This measure, however, would meet with much opposition; the seven members for Ghent would vote against any change in the present duties on manufactured cottons. The Belgian tariff had in several instances been modified in a liberal point of view. The French Government, according to M. C. Mæren, seems anxious to give a liberal turn to the tariff; but, notwithstanding their strength, the present rulers of France were obliged to withdraw their liberal intentions, in presence of the powerful industrial coalition of the northern departments and the deplorable ignorance of the principles of political economy throughout the whole population. The writer then stated that the Belgian Free Trade movement was progressing satisfactorily; that all the attention of its advocates was directed to the enlightening of the public mind on the question; that great results had been obtained already; and that, owing to the freedom they enjoyed, they confidently hoped for full success.

Sketch of the History of Flax Spinning in England, especially as developed in the Town of Leeds. By J. G. Marshall, *F.G.S.*

There is, perhaps, no branch of our principal manufactures, except that of cotton, in which the introduction of machinery and the factory system has produced more remarkable changes than in that of flax spinning; and, as the town of Leeds is the place where this new branch of industry first took root in England, and was successfully carried out upon a considerable scale, and the place which has hitherto taken the lead in the successive improvements introduced into the trade, it may be interesting to the Section to have a short sketch of the origin and progress of flax spinning brought before them whilst they are here.

The first essay in flax spinning in Leeds was made at a small mill driven by water, called Scotland Mill, about four miles from Leeds, by my late father, John Marshall, in partnership with Samuel Fenton of Leeds, and Ralph Dearlove of Knaresborough. This was in 1788 and 1789.

The wonderful success and large profits attending the introduction of Arkwright's invention into cotton spinning had about this time attracted general attention to mechanical improvements applied to manufacturing purposes. The spinning of flax by machinery was a thing much wished for by linen manufacturers. It attracted the attention, amongst others, of Mr. Marshall, who was so strongly impressed with the advantageous field for invention and enterprise offered by flax spinning, that he devoted himself entirely to the new enterprise.

It appears that some attempts at flax spinning had already been made on a small scale at Darlington, and some other places, as the first spinning machines used at Scotland Mill were on a patent plan of Kendrew and Co. of Darlington. This did not answer; experiments were made, and a patent taken out for a plan of Matthew Murray's, then foreman of mechanics with Mr. Marshall.

In 1791 a mill was built in Holbeck, Leeds, and at first driven by one of Savery's steam engines, in combination with a water-wheel, but in 1792 one of Boulton and Watt's steam engines of twenty-eight horse power was put down. In 1793 there were 900 spinning spindles at work. We may take this small item as our first statistical datum of flax spinning in Leeds.

I may here describe an important difference between the state in which the raw material flax is presented to the spinner and that in which cotton, wool, or silk is found previous to being manufactured. The fibres of cotton, wool, and silk are supplied by nature already in their finest state of subdivision; they require merely to be straightened and formed into a continuous thread. In raw flax, on the other hand, the ultimate fibres, which are very fine, are united by a gummy matter into broad strips or ribands, and a very operose process, called heckling, is required to subdivide the material into finer fibres before the spinning process can begin.

In the earlier stages of flax spinning this preparatory process was performed entirely by adult men, called hecklers.

As soon as the flax spinning by machinery began to increase considerably, the demand for the labour of the hecklers enabled them to obtain high wages (as much as two guineas a week, if they worked), and, as they were combined in Trades Unions, and enforced the old limitations on the number of apprentices, they became possessed of a species of monopoly, extremely troublesome and prejudicial to the progress of the trade. In fact no large extension or well-organized system was practicable so long as this barrier remained on the threshold. A patent for a heckling machine by which this process could be performed without the assistance of adult labour was taken out in the name of Matthew Murray, about 1805. Its introduction was resisted at first by the men with much violence and intimidation, but, being firmly persevered in, it became an established portion of the system. It was introduced gradually into general use in the trade, and had the effect of neutralizing the monopoly of the hand hecklers, without any sudden displacement of labour.

The next step was the establishment, by Mr. Murray, of a good machine-making shop for flax machines, which became the parent or precursor of many others, until Leeds became the seat of a very important branch of business in machine-making, chiefly for flax spinning.

The system of flax spinning had now become firmly established and well-organized, and made steady progress; but as yet was only applicable to the production of the coarser description of yarns, up to No. 16, or 16 lea yarn, which was manufactured at Barnsley into the coarser description of linens. The material employed was almost entirely Baltic flax.

An improvement was next introduced into the processes, called preparing, preceding the actual twisting of the fibres into a thread in the spinning machine; this improvement consisted in drawing the fibres through fine heckles or gills instead of rollers, thus giving the means of producing a much evener and finer thread, that is up to 40 or 50 leas, and for these yarns the finer flax of Flanders and Holland began to be used. This was about the year 1820, when the finer description of yarn came into very extensive use in the manufacture of the finer and better sorts of drills,—an important branch of the Barnsley linen trade.

We now come to the introduction of a very important improvement in the spinning process as applied to flax. I have adverted to the gummy matter which in raw flax unites or glues together the fine ultimate fibres into much coarser ones, and which it is the object of the heckling process to subdivide by mechanical means. The division so effected can only be imperfect; and it was found that the fibres could be more completely separated by saturating the material with water, which dissolves or softens the gummy matter in the spinning machine itself, when in the actual process of being drawn out and spun.

There is a somewhat singular history attached to the origin and progress of this invention of wet spinning. During the great war between England and the first Napoleon, it became a leading object of his policy to exclude English manufactures, and to encourage those of France. England had taken a decided lead in the cotton manufacture, but at that time, about the beginning of the present century, little had been done in England in applying machines to the linen trade. The linen trade of France has always been a very important branch of industry, linen being more extensively used by the bulk of the population in France than in England. Napoleon therefore wished, by encouraging the application of machinery to the linen trade in France, to make it a rival to the cotton trade of England. He offered a reward of a million francs for the successful application of machinery to the spinning of flax. This inducement brought forward Girard, who produced designs for a series of machines for preparing and spinning flax of great ingenuity and originality, including this plan of wet spinning. But what was the result so far as the linen trade of France was concerned? Girard could find no one in France with the enterprise and capital requisite to perfect and apply his invention. He had to come to England,—he had to come to the town of Leeds. A patent was taken out for his inventions in England, especially for the wet spinning, under the name of Hall, in 1816, and was taken up by Robert Busk of Leeds. Mr. Busk put up a considerable quantity of machinery on this plan, and produced by it yarn much finer than that usually spun. But he kept the new plan to himself; it was not tried by others; the improvements in the preparatory processes were not then sufficiently advanced to make fine spinning advantageous; the plan did not answer commercially, and was given up and forgotten. In 1826, however, it was revived in the shape of a new patent, with some modifications by Mr. Kay of Manchester. The validity of the claim to a new patent was disputed by the body of flax spinners, and finally set aside. The first spinning machine on this plan was put up at the works of Messrs. Hives and Atkinson of Leeds, and by them and by Messrs. Marshall chiefly the whole plan of wet spinning, with the requisite improvements in the preparing processes, was soon perfected and carried out.

A very wide horizon for the extension of flax spinning was now opened; yarns could now be spun much finer than before (from 50 up to 200 leas), and also cheaper, so as effectually to exclude hand-spun yarns from the whole range of linen manufactures except those of the finest cambrics and lace. For a time large quantities of these wet-spun yarns were sent from Leeds and Lancashire to the north of Ireland, and to France.

But the new mode of spinning soon spread into Scotland, Ireland, and finally into France, where it is now carried on (under the stimulus of a protective tariff, however) to a large extent.

Thus the object of the first Napoleon was at length accomplished, but not in the way that he intended; the result was a benefit to France, but only as the consequence of a still greater benefit to England. The present Emperor not long since rewarded the descendants of Girard for his invention, the fruits of which were so long postponed.

The later improvements which have followed the wet spinning have consisted in the application of the combing machinery, which has done so much for the worsted manufacturer, to flax-tow, so that a material capable of being spun to the finest yarn can be obtained from what is otherwise only of small value; and various processes have been tried for cleansing and softening the raw flax previous to its being spun.

The manufacture of sewing thread from flax commenced not long after the introduction of flax spinning by machinery, and has since increased and been a branch of the linen trade of considerable importance, a large proportion of the thread manufacture being carried on at Leeds.

The application of the power-loom to the weaving of linens has of late years been considerably on the increase, but to a much less extent than in the cotton and worsted manufactures, as the greater part of the linens made in the United Kingdom are still woven by hand labour.

I have thought it necessary to give this account of the nature of the successive improvements introduced into flax spinning, in order to make the statistical figures I shall now quote more intelligible.

The sources from whence the statistics of the linen and flax spinning trades may be derived are somewhat scanty, but, perhaps, enough may be stated to indicate the progress of the manufacture.

Imports of Flax into the United Kingdom.

Average of 5 Years.	Tons.	Average of 5 Years.	Tons.
1820 to 1824	27,875	1845 to 1849	68,879
1825 „ 1829	44,491	1850 „ 1854	76,254
1830 „ 1834	48,044	Year 1855	64,672
1835 „ 1839	61,213	„ 1856	84,352
1840 „ 1844	67,718		

Previous to 1820 the import of flax had increased but slowly, but from that time we see that the increase has been rapid, having more than trebled between that date and 1856—or from 27,875 to 84,352. We must add to this the home growth, which is, for Ireland about 22,000 tons yearly, on the average of the last ten years; for England and Scotland a small quantity, probably not exceeding 600 or 700 tons.

On the whole the annual consumption of flax in the United Kingdom will be about 100,000 tons, which, at an average price of £50, will make the yearly value of the raw material of the linen manufactures about £5,000,000.

From a Parliamentary Return we obtain the following particulars respecting the flax spinning of the United Kingdom.

Flax Spinning, 1850.

1850.	Factories.	Spindles.	Power Looms.	Horse Power.	Hands.
England and Wales	135	365,568	1083	4487	19,001
Scotland........................	189	303,125	2529	6425	28,312
Ireland..........................	69	326,008	58	3380	21,121
	393	994,701	3670	14,292	68,434
1856.					
England and Wales........	139	441,759	1987	4644	19,787
Scotland	168	278,304	5011	6246	31,722
Ireland	110	567,980	1871	7332	28,753
	417	1,288,043	8869	18,322	80,262
1856.					
Yorkshire					
Spinning only.................	37	149,201			
Spinning and Weaving	9	65,346	411		
	46	214,547	411		
1858.					
Leeds............................	11	160,300	510		8772

Here we see that the increase has been much the most rapid in Ireland, and that in Scotland there was during this period a small diminution. There are several circumstances to account for the rapid increase in flax spinning in Ireland. The North of Ireland is an old-established seat of the linen manufacture, chiefly of the lighter fabrics suited for the export markets, and especially for those of the United States of America, which since 1846 have so largely increased. Again, when the spinning by machinery was introduced into the North of Ireland, all the other branches of the manufacture were already established there—the weaving, the bleaching, the commercial establishments; and besides this, the flax, the raw material, was grown at their own doors. In England the linens manufactured have been more of the heavier and higher priced description, and suited more for the home market than for export. In Scotland the manufacture has consisted chiefly of the coarser and cheaper description of linens and of yarns, and the export of the latter has been materially affected by the high protective tariffs of the Continent, especially of France.

Much attention has of late been attracted to the object of encouraging and increasing the home growth of flax in England and Scotland; but the introduction of this species of agricultural produce into districts where it is entirely new is attended with many difficulties, and but little has yet been effected in that direction. Many attempts have also been made to introduce new fibrous materials from our Colonies and foreign countries for use in the linen manufacture; and the new material, jute, imported from India, and used chiefly in Scotland, has been of valuable service to the manufacturer of that country. I may now draw attention to the following Table, showing the exports of the linen manufacture of the United Kingdom:—

Years.	Linen Manufactures. Entered by the Yard.		Thread, Tapes and small Wares.	Linen Yarn.	
	Yards.	Value.		lbs.	Value.
1831 to 1835	65,571,770	£2,292,906	£74,883	1,297,603	£108,415
1836 „ 1840	78,468,192	2,901,296	97,723	12,383,825	637,121
1841 „ 1845	84,682,490	2,733,160	178,580	25,465,785	1,001,618
1846 „ 1850	99,346,562	2,957,491	249,301	15,876,004	726,425
1850 „ 1855	125,226,539	3,924,807	342,327	20,307,571	1,024,488

We see from this Table that the export of linens has nearly doubled in quantity and value between the years 1831 and 1855. The export of thread has increased more than fourfold. The export of yarns increased with very great rapidity up to the year 1845, since which time it has been nearly stationary, being checked by the high tariffs on the Continent before spoken of.

The next Table gives a comparative view, so far as can be made out from returns and the most reliable estimates, of the total extent of flax spinning in foreign countries, as well as in the United Kingdom, in the year 1852:—

	Spindles.		Spindles.
England	391,568	Russia	50,000
Scotland	295,125	Austria	30,000
Ireland	456,000	United States	14,550
		Switzerland	8000
United Kingdom	1,142,693	Holland	6000
France	350,000	Spain	6040
Belgium	100,000		
Germany	80,000		1,713,283

There are now engaged in flax spinning at Leeds 8772 persons.

I must now conclude my sketch of the remarkable rise and growth of flax spinning in England, a manufacture of which the town of Leeds has been to so large an extent the birth-place and centre of improvement, and which has since spread so widely, not only over the three divisions of the United Kingdom, but into all quarters of the world. If the extension of flax spinning has of late been more rapid in other quarters than in the town of Leeds, we must accept this fact as being at once a warning, and a friendly challenge to the renewal of the exertions by which Leeds was distinguished in former years.

On Phthisis in the Army. *By* F. G. P. Neison, *F.S.S.*

The Royal Commission appointed to inquire into the sanitary condition of the British army, the state of the hospitals, &c., published early in the present year an elaborate and most valuable Report, the result of an exceedingly comprehensive amount of varied and diversified evidence taken before them. As is already well known to the public through the medium of the press, a frightful rate of mortality takes place in the ranks of the army while stationed in the United Kingdom; but I shall here seek to engage your attention by only a brief recapitulation of the general results.

Abstract A.

Actual number of deaths in the		Deaths which would have happened according to the mortality in					
		England and Wales.		Out-door occupations.		Labourers in the rural districts.	
		No.	Differ. per cent.	No.	Differ. per cent.	No.	Differ. per cent.
Household Cavalry =	134	122	10·1	95	40·8	75	77·9
Dragoon Guards and Dragoons =	705	512	37·6	408	72·7	321	119·3
Foot Guards =	820	393	108·6	314	161·1	246	233·3
Infantry of the Line =	2823	1472	91·8	1208	133·6	958	194·7

These figures are certainly very remarkable, and afford a succinct view of the relation in which the different results stand to each other.

In the War-office Report itself a comparison is instituted between the actual mortality of the army and that which prevails in twenty-four large towns of England and Wales; but such a comparison is obviously at fault, for, as I have elsewhere fully shown, the gross mortality, not only of the whole kingdom, but of individual towns and districts, is greatly increased by the inclusion of the destitute, the dissolute, and the intemperate, as well as by the presence of many persons following occupations and trades of an unusually unhealthy character. Even in the rural districts of this country it will be seen, on referring to pp. 53–59 of 'Contributions to Vital Statistics,' that the mortality of the sixteen trades referred to in page 58 of that work is greatly in excess of the residue of the same districts.

The military are certainly free from the noxious influences peculiar to many trades and occupations. They do not suffer from destitution, nor can they be classed as a body with the notoriously intemperate. Every just comparison must, therefore, be made with some such classes as those forming the two last sections of the preceding abstract; but if the comparison be made with the general mortality of England and Wales (for the male sex), it will be found that the infantry of the line are subject to an increased ratio of mortality of no less than 91·752 per cent.

	per cent.
If the out-door occupations be made the standard of comparison, there is an excess amounting to	133·620
And in respect to labourers in the rural districts, the excess is no less than	194·658

being nearly three times the rate of mortality in this branch of the service that is found to take place amongst labourers in the rural districts at the corresponding ages.

In Appendix LXXI. of the Report of the Commissioners, as well as in the body of the Report itself, it is shown that among various classes exposed to severe night duty in the open air, such as the Metropolitan Police Force, and the railway employés, and also as otherwise since established in the London Fire Brigade, the rate of mortality is somewhat less than that for the country generally at the corresponding ages. In the same Appendix it is also conclusively shown, as admitted in the Report of the Commissioners, that the high rate of mortality in the army cannot be accounted for by the prevalence of intemperance. It further appears in the same Appendix, that whatever may be the primary cause of the greatly augmented mortality in the army, the immediate cause of it is the prevalence of consumption to an extent entirely unprecedented, and quite unknown in connexion with any other series of observations in the whole range of vital statistics; and without a corresponding increase from other causes, taking all branches of the army, the deaths from disease of the respiratory organs form about 60 per cent. of the deaths from all causes. The following abstract, however, places the results in a very distinct light:—

Abstract B.

	Number of Deaths from diseases of the respiratory organs.		
	England and Wales.	Actual.	Difference per cent.
Household Cavalry...	62·870	79	+25·656
Dragoon Guards, &c..	251·112	400	+59·291
Infantry..................	760·005	1641	+115·902
Foot Guards	203·560	555	+172·647
Total	1·277·547	2675	+109·387

The Commissioners, finding that the enormous mortality from consumption was the great scourge of the army, and that it was impossible to account for its prevalence from any of the causes already described, have, as most readers of the newspaper press are no doubt fully aware, attributed it mainly to overcrowding of the barracks.

In my examination before the Commission, and in the papers submitted by me, and forming the Appendix already quoted from, the effect of various employments on health, the influence of different forms of physical exercises, and the manner in which intemperate and irregular habits show themselves in the immediate cause of death, are very fully discussed. None of the questions, however, submitted for my consideration by the Commission, involved, I regret to say, the consideration of the influence of overcrowding or bad ventilation on the development of diseases of the lungs, or I should have been glad at the time to have submitted the hypothesis to whatever statistical tests were available. Nor has any other witness, nor the Commissioners themselves, supplied any facts or numerical evidence leading to the conclusion at which they have arrived in their Report, that overcrowding in ill-conditioned barracks is the main cause of the great destruction of life by inducing phthisis in the army.

From the deserved importance attached by the public to the deliberation of the Commission, it is in every way most necessary that such means as are available should be employed to test the practical value of the empirical opinions on which the overcrowding hypothesis is founded. The still imperfect returns made by the Registrar-General, however, prevent this from being done in that complete manner which is desirable, but they contain much available evidence, which can, although only by a considerable amount of labour, be brought to bear on the question.

Having devoted the necessary time for that purpose, I now beg to submit to this Section the results at which I have arrived.

That a sufficiently broad basis might be taken on which to found or establish a reliable test, I have taken the returns of the mortality for the whole of England and Wales, and the various districts thereof, for the seven years 1848–54.

As shown in details in Tables I., II., III., IV., V., and VI. inclusive, the mortality per cent. has been determined for the different terms of life, and for the various classes of diseases.

1st. For the whole of England and Wales.

2nd. For London.

3rd. For those districts of the kingdom in which the density of population varies from ·28—·72 per *hectar* (the *hectar* equals nearly 2½ *acres*).

4th. For districts in which the density varies from ·84—·99.
5th. For Lancashire (·28 or $\frac{7}{10}$th acres); and
6th. For the residue of the population of England and Wales.

If it be true that increasing density of population, particularly in the sense in which it is understood in regard to barracks' sleeping accommodation, has a tendency to augment diseases of the lungs more than all other diseases, then it is evident that districts in which the sleeping accommodation differs so widely must show a marked difference in the ratio of deaths taking place from phthisical causes. No doubt the results of the influence of a uniformly and generally increased density of population in a district which is not, in any considerable portion of it, highly intensified in its overcrowding, would be unfairly compared with the results of a district or section of population which is throughout overcrowded; but in London or Lancashire, and in the third district of England now under consideration, we have been long accustomed to hear reports through the "Health of Towns Commission," of great, and, in many instances, of major portions of them being overcrowded to a degree which shocks morality and the ordinary notions of common decency.

Into these details it is now unnecessary to enter; they are patent to all giving attention to questions affecting the public health. Although, therefore, there is no one district of the kingdom in which there is a uniform system of overcrowding, still there are many—and among them those now under review—in which the overcrowding of the large portions of them is such, that if the hypothesis be of any value, there must be at the least a slightly augmented ratio of death from consumption compared with the general ratio of increase from all causes. Let us see how far this is in agreement with recorded facts.

It must be clearly understood that the hypothesis on which the Commissioners rest their conclusions is not simply that overcrowding may induce phthisis in an increased ratio—that would probably be denied by no one.

In the army, the deaths from diseases of the lungs are absolutely, as well as relatively, to the deaths from all other causes, in a ratio so high, beyond all precedent and example, as to form a new and important problem for solution in vital statistics.

The hypothesis, therefore, of the Commissioners resolves itself into the following:—
"That 'overcrowding,' although it increases the general mortality, has the peculiar characteristic of intensifying the deaths from diseases of the lungs greatly beyond those from all other causes."

It will be found that the total excess of deaths above the average for England and Wales is 1981·57, while at the same ages, in diseases of the "respiratory organs" only, it will be seen, on referring to Abstract B. preceding, that there is an excess of no less than 1397·45 deaths, or at about 70 per cent. of the whole increase.

This result deserves the most careful and patient consideration. According to the mortality of England and Wales, the normal ratio of deaths from diseases of the "respiratory organs" is 44·48 per cent.; and yet of the whole excess of deaths from all causes, no less than 70 per cent., as appears by Abstract B., is due to the organs of respiration.

The full importance of this result will be perhaps better appreciated by the following illustration:—

Actual number of deaths from diseases of the respiratory organs	=2675·0
Normal number of deaths	=1277·6
Difference of excess	=1397·4=109 per cent.

If the residue of the deaths from all other causes whatever be viewed in this manner, the results are—

Actual number of deaths from all other causes	=1807·0
Normal number of deaths	=1211·8
Difference or excess	= 595·2= 49 per cent.

These results conclusively show that the condition of the army is such as to induce an excess of diseases of the organs of respiration, with a much higher intensity than all other diseases collectively; in fact, the excess of deaths from diseases of the organs of respiration, is considerably more than double that from all other causes.

This peculiar feature in the mortality of the army has not been observed in any other series of observations, and it is of the utmost importance to determine whether the solution of it offered by the Commissioners be the correct one.

Should their hypothesis be found not in accordance with facts and experience, then the most serious consequences must result from it to the sanitary state of the army; as, without the true solution, there is little chance of effectual remedies being applied.

In Tables I. to VI. inclusive, appended, are given the ratio of mortality per cent. from all specified causes at the different terms of life; but I shall now refer simply to the results for the soldiers' ages as given in the following abstract of the tables.

Abstract C.

Ratio of Deaths from each Cause to the total Deaths from all Causes in the following Districts.

(Soldiers' Ages.)

Group of diseases.	England and Wales.	London.	Lancashire.	Density ·28–·72.	Density ·84–·99.	Least Dense.
1. Phthisis	37·0	35·2	36·0	35·4	36·2	43·7
2. Residue of tubercular diseases, and diseases of the respiratory organs	9·5	9·6	10·3	10·2	9·2	8·4
	46·5	44·8	46·3	45·6	45·4	52·1
3. Zymotic diseases	19·1	22·6	21·4	20·3	17·6	11·6
4. Diseases of the nervous system and digestive organs	12·6	12·5	12·5	13·5	13·3	10·7
5. Sudden and external causes	11·0	8·2	10·7	10·9	11·7	15·3
6. Other diseases	10·8	11·9	9·1	9·7	12·0	10·3
7. All causes	100·0	100·0	100·0	100·0	100·0	100·0

A careful examination of the results given in this abstract, leads to a conclusion quite at variance with the hypothesis of the Commissioners. In fact, in the densest districts, the mortality from diseases of the lungs is relatively to the deaths from all causes much less than in the more thinly-peopled districts.

In London the deaths are .... 44·8 per cent.
In England and Wales .... 46·5 „
And in the residue of the country, after deducting the districts enumerated in Abstract C. .... 52·1 „

It will be seen that the effect of density and overcrowding is not to intensify pulmonary disease so much as the class of zymotic diseases. The third line of this abstract gives a striking illustration of this; reading from the last column toward the first, it will appear that the relative amount of zymotic diseases to those from all causes increases gradually, and almost uniformly, with the ratio of density, from 11·6 per cent. in the least dense districts to 22·6 per cent. in London, the most closely-packed district; the results for England and Wales, which include all the districts, being of course intermediate. The diseases of the nervous system and digestive organs exhibit a somewhat remarkable uniformity throughout all the groups.

It is when the results of the mortality in the army are given in the particular *form* of expression adopted in the preceding abstract, that they appear anomalous, the mortality from diseases of the lungs being among the most fatal.

Household Cavalry	59·0 of the whole deaths.
Dragoon Guards, &c.	53·9	do.
Infantry of the Line	57·3	do.
Foot Guards	67·7	do.

These results are very singular, and will appear still more so if it be kept in view—throwing out of comparison the Household Cavalry, a very small body, and therefore subject to marked fluctuations—that as the general mortality increases so does the ratio of deaths from diseases of the lungs increase. If, therefore, overcrowding were the main cause of developing so inordinate an amount of consumption, the barrack accommodation for the different branches of the service should be found contracting in the order in which the general mortality, as well as that from consumption, increases; but it happens to be quite otherwise. A careful examination of the preceding facts, it is believed, does anything but support the hypothesis of the Commissioners now under consideration.

There is, however, another and in some respects a more simple, and in unskilful hands a safer, way of solving this question, and that is, instead of taking the ratio of the mortality from "one cause" to the mortality from "all causes," to determine the actual rate of mortality from "each cause," and I have accordingly placed all the preceding results in that form. The detailed Tables hereto appended give the results for various terms of life; but in the abstract to which I ask the attention of the Section, reference will be made to the results for the soldiers' ages only. In the preparation of the following abstract, the actual mortality per cent. at the given ages was in the first place determined, and then the differences per cent. between these results and the corresponding ones for England and Wales were found; and the abstract will therefore show, for each cause of death in the army, whether it is in greater or less activity than in the country generally.

Abstract D.

Differences between the Mortality per cent. in the following districts, and that for England and Wales.

(Soldiers' Ages.)

Group of diseases.	London.	Lancashire.	Density ·28—·72.	Density ·84—·99.	Least Dense.
1. Phthisis	+ 14·0	+ 19·6	+ 4·8	− 12·4	− 14·8
2. Residue of tubercular diseases and diseases of the respiratory organs	+ 19·8	+ 32·3	+ 17·7	− 13·5	− 36·5
	+ 15·2	+ 22·2	+ 7·5	− 12·6	− 19·0
3. Zymotic diseases	+ 41·7	+ 38·0	+ 16·7	− 17·2	− 56·3
4. Disease of the nervous system and digestive organs	+ 19·8	+ 22·2	+ 16·7	− 4·8	− 38·9
5. Sudden and external causes	− 10·0	+ 20·9	+ 10·0	− 3·6	+ 9·1
6. Other diseases	+ 32·1	+ 3·7	− 1·8	− 0·9	− 31·2
7. All causes	+ 19·9	+ 23·1	+ 9·6	− 10·2	− 27·8

In viewing the preceding abstract, it is right to explain that the results in the first line are of the most importance, as in the army *phthisis pulmonalis* constitutes about 80 per cent. of the deaths from diseases of the lungs, and about 50 per cent. of the deaths from all causes. This being explained, the results in Abstract D are, as bearing on the applicability of the hypothesis in question on the causes of the mortality in the army, even more remarkable than those in Abstract C. In every instance, except one, the differences between the mortality per cent. in the respective districts from phthisis, and that for England and Wales, are less than the differences between the mortality from all causes, showing that death from phthisis is more positive in its determination—in other words, less subject to fluctuation, and less affected by external causes, than the other diseases in the aggregate.

In London, the densest of the districts, the increase beyond that of the country generally from death by phthisis is 14 per cent., while the increase from all causes is about 20 per cent.; but in the least dense portion of the kingdom, as shown in the last column of Abstract D, the decrease from phthisis is precisely 14·8 per cent., but that from all causes 27·8 per cent., reversing exactly the positions held by these diseases in the army, as already pointed out, in which it was shown that the deaths from diseases of the lungs were in excess of the normal number 109 per cent.; but the deaths from other causes were in excess only 49 per cent. There appears, therefore, no relation between the hypothesis advanced by the Royal Commission and the causes of the actual increase of mortality which has taken place. If the great havoc made in the ranks of the British army while at home had been occasioned through deaths from zymotic causes, then the hypothesis under discussion would, if applied to that class of diseases, have held good, and the conclusion they have arrived at might have been suggestive of ulterior proceedings, beneficial to the brave men who have to fight our battles, improving to their moral conditions and physical power, thereby enhancing the financial resources of the empire.

The results in the third line of Abstract D are exactly confirmatory of those in Abstract C, showing that density of population is only powerful in developing zymotic diseases. It is somewhat remarkable that the results of the two abstracts, in which the mode of expressing the relation of the facts recorded is so decidedly different, should agree precisely, showing, in both instances, that the only diseases which follow the order of density in their development is the zymotic class.

If in Abstract D the results for the deaths from the whole class of diseases of the "respiratory organs" be taken into consideration instead of those from *phthisis pulmonalis*, only the same reasoning and argument will be found to apply, the deaths from consumption being always more constant, less affected by external circumstances, and showing less disturbance in their development in the different districts than the remaining diseases. In fact, compare in any considerable portion of the population, which is either more or less crowded than the average of the kingdom, the deaths from phthisis and diseases of the respiratory organs, and the ratio will be found always subject to less perturbation than the residue of all other diseases.

If the hypothesis of the Commissioners were therefore well-founded, this would not be so, for districts in which there was a large amount of overcrowding would, when compared with those thinly populated, show, to a lesser or greater extent, the well-marked peculiarity of the mortality in the army of intensifying deaths from consumption more than those from other causes. The present investigation, however, shows that overcrowding produces the very opposite effect, and that deaths from consumption are increased in a much less ratio than the deaths from other causes.

If the methods followed in this communication, and the various conclusions thence deduced, be thoroughly reliable, then it is obvious that many of the recommendations made by the Royal Commission on the sanitary state of the army, however valuable they may be on other grounds, will not, if carried out, produce the intended effect of reducing the ratio of deaths from diseases of the respiratory organs among our soldiers to the normal conditions of the country generally.

It was proposed to discuss in this paper the statistical value of the Commissioners' hypothesis only, and not to enter on the consideration of the real cause of the high ratio of deaths from consumption in the army. Enough, it is believed, has been already adduced in Appendix LXXI. of the Report to indicate the chief cause of not only the general high rate of mortality, but also of the very unprecedented and frightful destruction of life by diseases of the lungs.

On the History of Prices of 1857 *and* 1858. *By* William Newmarch.

On the recent History of the Crédit Mobilier. By William Newmarch.

On the Race and Language of the Gipsies. *By the* Rev. T. W. Norwood, *F.G.S.*

The Gipsies are said to have been first seen in Europe about the year 1417; before which time their history is involved in very great obscurity.

A wide-spread and persistent tradition amongst themselves declares them to be Egyptians; which they certainly are not, however that denomination arose, and whatever credit may seem due to its very general circulation. Many attempts have been made to account for this tradition, but without any success.

They arrived in England some time in the end of the fifteenth century. Polydore Virgil seems to be the first author that mentions the English Gipsies: he speaks of them as "Assyrians" or "Egyptians," in terms of strong reprobation. Wherever they went, they early made themselves detestable by their vices and cunning; and consequently they have been persecuted throughout Europe in a way which makes us wonder that they were not all exterminated. It remained long unknown whence the Gipsies came, and to what race of men they ought to be referred; but it was at length discovered that they are an emigration from India, by researches into their strange unwritten language. This disclosure is due to the scholars of Germany; and particularly to Grellman, who wrote his "Dissertation" in the last century. The same conclusion might have been suggested from considerations of figure, feature, and colour; but the best criterion, upon the whole, that we have at present in such questions, is the internal testimony of language. Language is the best test of race, hitherto.

Grellman arrived at the decision, by a limited comparison of "Gipsy" with "Hindustani," that at least twelve Gipsy words out of every thirty were Indian. We know now, after a wider examination, that this proportion has been almost doubled; and also that the Indian words in Gipsy are nearly all of "Sanskrit" origin. "Gipsy" is now, in fact, *proved* to be a dialect of "Sanskrit," very much overlaid with foreign words, such as a wandering nation would be sure to adopt; and also considerably differing, in original character, from any other known dialect of the Sanskrit speech.

We do not despair of finding, in the East, an idiom more closely allied to Gipsy than any with which we are yet acquainted. At what time, or from what motives, the Gipsies left India, no one has been able to determine.

The author of this paper read to the Section a list of sixty words (out of a large vocabulary collected orally from the Gipsies by himself), each of which is a genuine Sanskrit word, and common at the present day to the Gipsy and Hindustani dialects of that language. These were names of *numerals, elementary ideas,* and *familiar natural objects,* such as he judged likely to have been brought from the original settlement of the race.

Doubtful words in "Gipsy," not yet traced to any language, are their names for *coins,* articles of *clothing,* and things connected with *religious worship.* A list of these was also read. They may have been changed in travel. It was shown that Gipsy has much more in common with Greek and Latin (especially with Greek) than with any other European languages. In some of its *suffixes* it closely resembles the very ancient Islandic and Lithuanian dialects. It has great facility, like Greek and German, for coining new words by compounding old roots. This is a sign and property of very ancient languages. Many specimens of Gipsy conversation, orally collected, were read, with their exact pronunciation, to the Section. "Gipsy" and Gipsyism are fast declining and dying out in England; meanwhile we remember the words of Dr. Johnson speaking on the whole subject of language:—"I am not very willing that any language should be totally extinguished. The similitude and derivation of languages afford the most indubitable proof of the traduction of nations, and the genealogy of mankind. They add often physical certainty to historical evidence of ancient migrations, and of the revolutions of ages which left no written monuments behind them."

Notes on Indian Fibres, illustrated by prepared Specimens. *By* J. H. Sadler. (*Communicated by* Colonel Sykes.)

The natives of India were at an early period acquainted with the art of spinning and weaving, and described as weaving cloth made of fibres from trees more beautiful than from sheep's wool; and in the Institutes of Menu, written before the Christian era, we learn that the sacrificial thread of a Brahmin must be made of cotton; that of a Cshatriya, of Sana thread only; that of a Vaisya, of woollen thread. It is supposed, that the Sana thread was most probably that of the Sunn (*Crotalaria juncea*). Buddha, in his sermons preached 600 years before Christ, interdicted to women the use of certain muslins because they were too fine for decent concealment.

The Ambaree (*Hibiscus cannabinus*), or Mesta plant of Bengal and Palungo of Madras and Ambaree of Western India, is very generally cultivated all over India; it grows from three to seven feet in height, the stem straight and simple; it is usually called Indian Hemp, or one of the Brown Hemps of Bombay.

Bandikai of Madras, and Bendy of Bombay (*Hibiscus longifolius*), grows to a great height and very straight, with a few branches, and with pyramidal pods, which, when young, are filled with a large proportion of mucilage, and are gathered and cooked as a vegetable; the fruit is also used to thicken soups, and the seeds added like barley to it; they may be also roasted as a substitute for coffee.

The Deckanee Hemp, Ambaree, grows with a straight clear stem from four to seven feet in height; its leaves are in general used as an esculent vegetable by the natives, and taste something like sorrel.

Rouselle (*Hibiscus Sabdariffa*) is cultivated in most gardens, because its calices as they ripen become fleshy, and are of a pleasant acid taste, and are employed for making tarts, as well as an excellent jelly.

Marool of Madras, or Bowstring Hemp (*Sanseviera*).—The leaves when cultivated are from three to four feet long; the fibre extends their whole length; from these fibres the ancient Hindoos made a very tough elastic thread, of which they made their bowstrings.

The Naroo and the Naroo T fibres being both new ones, no description is yet given, except that they are natives of Malabar.

The Bunochra (*Urena lobata*), and the Kungio (*Urena sinuata*), are from two weeds common in most parts of India.

The Mudar, or Mudder, is met with in both the southern as well as the northern parts of India, in considerable quantities in all uncultivated lands, and encroaches even on cultivated grounds. It is a plant with broad, fleshy, glaucous-coloured leaves, and which, when pierced, gives out a milky juice from every part; this is called Ak and Mudar in northern, and Yercum in southern India. It is the *Asclepias gigantea* of botanists. Its juice and the powdered bark of its roots are employed medicinally by the natives of India in cases of leprosy and other cutaneous affections; lately its milky juice has been collected by making incisions into the plant, and preparing it as a substitute for caoutchouc and gutta percha.

The pods of the Mudar are full of a beautiful glossy silk down, which the natives spin into a beautiful soft thread; from intimation given, this article will soon come into great use in the trade of this town (Leeds). The native mode of separating the fibres of the Mudar is tedious, rude, and injurious; notwithstanding it is one of the strongest fibres known, as, from experiments made by Dr. Wight, it bore 552 lbs., when *Crotalaria juncea* bore only 404 lbs., and a small cord bore 3 cwt., without showing the least symptom of distress; yet by the samples now produced it certainly seems better adapted for purposes of flax than hemp; and well will it be for both housewives and servants if ever it should be brought into general domestic use instead of flax, for common washing with soap and water will bleach the fibre a perfect white, beautiful and glossy.

The *Bromelia Ananas*, and *Bromelia Pigna*, also the Karatto fibres, are all of the different qualities of *Bromeliaceæ*, or the pine-apple tribe. It appears the pine-apple was first introduced into India by the Portuguese; it has now become so naturalized as to appear indigenous: it grows in enormous quantities in various parts of India; indeed so plentiful, that a boat load of the fruit has been sold for one rupee, or two shillings, at Sincapoor and Malacca.

The *Perida fœtida*, or the Vegetable Silk: there can be no doubt but that this extraordinarily beautiful article will ere long enter largely into every description of ladies' apparel.

The Neilgherry Nettle (*Urtica heterophylla*), or the Vegetable Wool: indeed so greatly does this wool resemble the sheep's wool, as to deceive some of the best judges in England.

The fibre is long in staple, and by the two sticks now shown, and which were hackled by the Messrs. Marshalls and Messrs. Hives and Atkinson, proof is afforded how well it is adapted for flax-spinning machinery; and when flax spinners shall provide warps of this material, cotton warps might be dispensed with, and a warp of great strength be introduced, which so corresponds with all the essentials of real wool, that when mixed with wool, they will both take the same dyes, mill and dress together, and will certainly manufacture a good cloth.

The flax of India, according to Dr. Roxburgh, is mostly cultivated on account of its seed, and the part which in most other countries is most valued, is there thrown away. The Belfast Chamber of Commerce observes, that as India annually exports nearly 100,000 quarters of seed to Great Britain and Ireland, it has been calculated that the plants producing this quantity of seed would yield annually at least 12,000 tons of fibre, value say £500,000, all of which now goes to waste. There can be no doubt, therefore, that the question is one of immense importance not only to this country, which requires such immense quantities of flax fibre, but to India, which produces such enormous supplies of seeds, and is supposed to waste so much of valuable exportable material. There can be no doubt that the very best flax may be produced in India, and always at a remunerating price; for labour there is so plentiful and cheap, that whatever may be the extent of cultivation entered into, there need be no fear of being undersold by any nation upon earth. It has been said, that if any party in India could supply this kingdom with 100,000 tons of Indian flax at this time, he might go on shipping as fast as he could, and never feel the least fear of overstocking the market. Instructions have been given for a considerable supply of four of the different India fibres.

The silk of the wild silk-worm ought to be noticed, as the fibre or thread is fifteen times stronger than that of the common silk. No doubt it will be of importance to manufacturers of what is called spun silk, as by proper looking after, an immense quantity, now completely neglected, might be collected and brought to be of great advantage to them.

India produces some 200 varieties of fibres for examination, and it is to be hoped for future use in Europe. The India House Museum contains specimens, not only of these, but of every article of raw and cultivated produce of India,—minerals, gums, dyes, woods, and cereals, and specimens of all the textile fabrics and works of art and taste: the whole are open to the inspection of the public, and manufacturers can obtain any desired information upon application.

Mr. Dickson of Leeds has a case of prepared Indian fibres in the Exhibition of Local Industry.

For elaborate, complete, and instructive papers upon India fibres, reference may be made to vol. ii. of the Transactions of the Society of Arts, p. 366, and to vol. v. p. 17, where the lamented Dr. Royle will be found to have nearly exhausted the subject.

An Essay on Distinctions between Money and Capital, Interest and Discount, Currency and Circulating Medium, essential to be observed in the Reform of our Monetary Laws. By HAMER STANSFELD.

The author sets out by stating that his ideas are not offered as the speculations of a profound political economist, but as the attempt of a merchant (retired from business on the ground of health) to account for monetary convulsions, and to find, if possible, some means of mitigating their frequency and severity. The conclusions at which he arrives as to the distinctions between money and capital, and between interest and discount, are thus summed up:—That money is a certificate of value, and may be the product of either capital or credit. That capital is the product of labour alone. That money is a security for obtaining and transferring at all times its equivalent specified value in capital or in any kind of wealth. That capital is that portion of wealth which is used in reproduction, and is the object of transfer through the medium of money. That debts are contracted in money, and not in capital. That interest is, in a great degree, a charge made for the risk of lending money on credit.

That discount is the allowance made for paying off that charge for credit with ready money.

That interest may be given either as a remuneration for the use of the capital transferred by the money, or for the use of money itself.

That discount is given only for the use of money itself.

That the rate of interest depends on the demand and supply of capital, and on the degree of risk incurred.

That the rate of discount depends on the supply and demand of ready money, and and on the degree of risk incurred; and as in this country provincial bank notes are convertible on demand into legal tender money, the rate of discount here fundamentally depends at present on the demand and supply of legal tender money.

To the question, What is currency? the writer replies, "Coin and bank notes;" but he points out that these form only a small portion of the great wheel of circulating medium, which embraces credit and every thing that is a medium for circulating value. "The amount of currency in circulation in the wholesale trade is, in relation to the aggregate of circulating medium, but as a drop in the ocean of credit on which it is carried." Hence the writer asks, "Must not the attempt by law to adjust the circulating medium and prices, by regulating the amount of bank notes, be as futile as the endeavour to regulate the ocean and its tide by damming up the streams?" The final conclusion at which Mr. Stansfeld arrives is, "That were the laws of nature not counteracted by the laws of man, but left as free in their action on money as on capital; and were the duty of the legislature confined to the taking care of the quality of the currency, by ensuring the convertibility of the bank note, leaving the quantity to take care of itself, the enormous disproportion between the amount of credit liabilities and ready money would be diminished, and the frequency and severity of monetary panics would be mitigated, if not entirely averted."

On the Sewing Machine in Glasgow, and its Effects on Production, Prices, and Wages. By JOHN STRANG, *LL.D.*

Dr. Strang mentioned the different kinds of sewing machines, with the various improvements that had been effected in those implements. The cost of the best machines now in use varied from £25 to £30 each, and some were produced of an inferior kind in America so low as 10*s*. each. The better class of machines now in use were calculated to make almost everything formerly executed by the needle or even awl, and it was affirmed that the finer or more difficult the work, the more benefit from the machine. One of the latest improved machines would complete a thousand stitches in a minute, and the use of the instrument was becoming more and more general throughout the great manufacturing marts of the world. The important question then arose, had the introduction of sewing machines interfered with hand labour, and if so, to what extent? Limiting the inquiry to Glasgow, where the introduction of sewing machines has been recent and their adoption rapid, there being at present about 900 at work in that city, Dr. Strang stated that while these machines had greatly increased the power and facility of production, and consequently lowered the price of the manufactured article, they had only displaced the most unprofitable portion of hand needle-work, and had indeed tended rather to increase than to diminish the wages of those engaged in this sphere of labour. Among other instances of this he stated that the wages of a handy female attending each machine were from 7*s*. to 10*s*. per week, whereas a mere sempstress could scarcely earn half that sum, and that, too, through long protracted labour.

Water Supply to Great Towns—its Extent, Cost, Uses, and Abuses. By JOHN STRANG, *LL.D.*

Dr. Strang showed by an elaborate array of statistical facts, the present and projected water supply of some of the leading towns of the Western world, with the extent and cost of such supply. He glanced at some of the social disadvantages, and even evils, which have arisen, or may still further arise, from rendering water the too easy agent for the removal of impurities which should be transported otherwise, and thus converting many once pellucid streams, upon which cities are founded, into deleterious and noxious common sewers, detrimental to comfort and hostile to health. The amount of the water supply, and its cost, for the several cities and towns h enumerated, were given in the following tabulated form :—

Towns.	Population within bounds of supply.	Daily supply.	Daily supply for each inhabitant.	Cost of undertaking.	Daily supply for every £ expended.	Prospective supply daily in addition.
		Gallons.	Gallons.	£	Gallons.	Gallons.
London ..	2,667,917	81,025,842	30·3	7,102,823	11·4	..
Paris	1,100,000	26,350,000	24·	800,000	33·	20,000,000
Hamburg..	160,000	5,000,000	31·25	170,000	29·50	..
New York	713,000	28,000,000	39·27	1,800,000	15·5	..
Manchester	500,000	11,000,000	22·	1,300,000	8·5	14,000,000
Liverpool..	500,000	11,000,000	22·	1,640,000	7·	..
Leeds	153,000	1,850,000	12·	283,871	7·	..
Edinburgh	215,000	4,800,000	22·3	456,000	10·5	2,000,003
Aberdeen ..	65,000	1,200,000	18·4	50,000	24·	..
Dundee....	96,000	1,750,000	18·2	139,000	12·5	..
Greenock ..	40,000	2,112,500	52·8	90,000	23·4	..
Paisley....	48,450	1,021,452	21·	60,000	17·	..
Glasgow ..	420,000	16,710,000	39·8	651,199	26·	20,000,000

In conclusion, Dr. Strang stated, that from the statistical figures he had brought forward the following results might be drawn:—

1st. The fact of a present prevailing anxiety for an abundant and pure supply of water, irrespective of every difficulty, and at any cost.

2nd. The fact of a growing consumption of water on the part of those who have had it at command, and the necessity of limiting as far as possible the quantity allowed to run to waste.

3rd. That while the increasing abundance of water has necessarily added to the comfort and health of the people, by enabling them to have baths and other conveniences easily and cheaply, it has at the same time tended to encourage city and house impurities being improperly carried away, and that too in a manner calculated rather to transfer than to abolish nuisances.

4th. That an abundance of water brought within every house, without due attention being paid to the carrying off to a distance, or otherwise separating, the solid sewage from the water before it falls into any stream, is a serious and growing evil which ought to be forthwith remedied, particularly on the part of those towns and villages which line rivers from which other towns are deriving their supply of water.

5th. That an abundant supply of water is, in short, a limited benefit, unless provision be at the same time made for a perfect and profitable riddance of the increased sewage which it invariably creates.

On Subjects connected with Crime and Punishment. *By* W. M. Tartt, *F.S.S.*

After noticing how much there was still to be done towards carrying into effect the improvements connected with our criminal legislation, Mr. Tartt briefly adverted to the anomalies in prison discipline, and went on to suggest that there are discrepancies as much opposed to any established principle in some of our preliminary proceedings. He took as one of his examples the administration of the *Criminal Justice Act of* 1855. As a measure of economy, it was allowed that it had been eminently successful. A table which he had compiled from the accounts of a single county, for the last five years, gave the average cost of trials at Quarter Sessions, at £9 2*s*. 3*d*. each, while the summary convictions under the Criminal Justice Act had only cost £1 3*s*. 4*d*. each (for the whole kingdom they were £1 13*s*.); and the saving during two years, in one county alone, had been £2806. But he dwelt at some length upon the uncertainty and total absence of classification, with which the different periods of imprisonment are inflicted, and the frequency with which previous convictions are overlooked; and though high authorities have seen insuperable difficulties in the way of establishing any *fixed rule*, he insisted upon the possibility of some better system being devised. At present it is a *lottery of punishments*, which ought not to exist. He then took up the *Juvenile Offenders' Acts*. For the administration of these, he showed that we have the guidance of principles carefully and rationally defined by Mr. Barwick Baker of Hardwicke, whose experience and unwearied attention to the subject give him the weight of authority. The course Mr. Baker proposes is, with rare exceptions, to inflict for a first offence 7 days' imprisonment; for a second offence 14 days, with (invariably) the Reformatory. Should it fail in its effect, he recommends that, on a relapse into crime, the offender should be sent to the quarter sessions, where he may be sentenced to penal servitude; and for this mode of treatment satisfactory reasons are adduced. Yet what is the practice? The terms of imprisonment, coupled with a sentence to reformatory discipline (which is often reserved for a third or even a *fourth* offence), vary from a week up to the *maximum* of three months, *frequently without any perceptible reason*; juvenile offenders are dealt with, both at petty sessions and at the police courts, as though the *Acts* had no existence; and when reformatory discipline has failed, and fresh crimes have been committed, instead of sending the offender to be treated as Mr. Baker recommends, the mischievous system of repeated short imprisonments is, too often, again resorted to. In proof of it, several examples were cited. Returns were also referred to in evidence of the partial manner in which the law had hitherto been carried into effect as respects the contributions to be levied upon parents towards the support of their children while under detention. It was inferred from official papers, that the number of parents actually contributing was not a third of those who might be compelled to do so.

But whatever may have been the errors committed in applying the law, it is willingly allowed that there can be no doubt as to the beneficial effects of the reformatory system in the diminution of crime. Mr. Tartt gave sufficient facts to prove that, out of 100 boys, 50 may be considered as reclaimed; 25 only as certainly bad; and the remainder are either middling, doubtful, or lost sight of. As regards its individual effects, all this (he observed) is very satisfactory; indeed it would be so if we reduced our estimate of the successes by one half; and, in other respects, the good effects were equally shown. When it was the practice to sentence juvenile offenders to two or three weeks' imprisonment, they were, on the expiration of their terms, usually met or welcomed by their former companions, and were reconducted to the haunts and habits from which they would, often, have been willingly freed. The consequence was a continued course of petty crime, followed by punishments repeated with more or less frequency, according to the degree of vigilance in the police or of dexterity in the criminal. Since it has been permitted to send them to a reformatory, society is relieved from their depredations during the time of their detention; the schools and associations for crime are broken up; and even if the individual is not reclaimed, he is generally removed from the scene of his former pursuits; or is relieved by employment, either at home or abroad, from immediate temptation. That the aggregate of crime has thus been lessened there cannot be a doubt. The *Judicial Statistics*, prepared at the Home Office, and several other returns, were cited in evidence. In connexion with his subject, Mr. Tartt referred to the 'Report on Criminal Returns,' which he presented to the Section at last year's meeting. The introduction of changes (he observed) is slowly admitted, partly on account of the difficulty they present in comparing previous with succeeding years, and partly on account of the official arrangements not being sufficiently extensive for the superintendence of more extensive work; but he again urged the adoption of two of the suggestions contained in the Report; one of them, the careful distinction between *resident* and *non-resident* offenders; the other, the establishment of something similar to the *Casiers Judiciaires* in France, for acquiring better knowledge than we can obtain at present of a criminal's antecedents. Whatever tended to an improved knowledge and classification of the criminal, would assist in the suppression of crime.

Brief Review of the Operations in the Bank of England in 1857. *By* R. VALPY.

On the Results of Free Trade. By H. WALKER.

MECHANICAL SCIENCE.

On the Progress of Mechanical Science. Address by the President.

IN opening the business of the Section, I have to congratulate you upon the encouraging prospects which our meeting in this great mart of industry is calculated to afford. This large and important district is only just recovering from a state of intense excitement and a burst of loyalty that has reverberated from one extremity of the Riding to the other. In these rejoicings I have naturally taken a deep interest, and, now that the royal visit is over, a meeting for the extension of science and useful art is probably the most appropriate conclusion of the festivities which have occupied the attention of this town for the last two weeks.

On a former occasion, when I had the honour of occupying this chair, I endeavoured to combine in a condensed form a review of such improvements in mechanical science as had been effected during the successive intervals between the Annual Meetings of this Association, and, conceiving that a short account of what has taken place during the last few years may not be unacceptable, I have on this, as on previous occasions, ventured to direct your attention to a succinct retrospect of what I consider new and valuable in mechanical art.

In Mechanical Science and General Engineering this country continues to maintain its high position in new developments and continued progress, and the almost innumerable patents weekly taken out under the new law are remarkable indications of the activity and inventive powers of this country. It is not yet thirty years since the introduction of malleable iron as a material for ship-building took place, and a much shorter time has elapsed since it was first applied to the construction of bridges. We have all of us heard of the Tubular system so successfully applied to the bridges across the Conway and Menai Straits; now it is extensively employed in every quarter of the globe, and there is no span within the limit of one thousand feet but what might be compassed by the hollow girder bridge with security and effect. These discoveries are of immense importance to mankind, and where they are carried out with skill and a strict adherence to sound principles of economy and science, they give to the engineer of the present day a power which in former times it was impossible to realize.

Steam Navigation.—In this department of practical science, although much has been done, yet much remains to be accomplished in giving to the iron ship uniformity of strength and security of construction. With respect to vessels of such complex form, bounded by such a variety of curved surfaces, we are yet much uninformed as to the precise points of application of the material, in order to attain the maximum of strength combined with lightness and economy in the distribution of the material. These are data yet to be ascertained, and it will require long and laborious experimental researches before the facts are clearly known and established; much has, however, been accomplished in the absence of these data, and I may safely refer to that noble structure the *Leviathan*, which, with all her misfortunes, is nevertheless a most magnificent specimen of naval architecture. The Cellular system, so judiciously introduced by Mr. Brunel, is her great source of strength, and I am persuaded that she will stand the test (which I have recommended in other cases) of being suspended upon the two extreme points of stern and stern with all her machinery on board; or, these conditions being reversed, I believe she may be poised upon a point in the middle like a scale-beam, without fracture or injury to the material of which she is composed; her cellular construction and double sheathing round the hull, and the same formation on the upper deck, give to the vessel enormous power of resistance, and her division and subdivision by bulkheads ensures a large margin of security in whatever circumstances she may be placed. In fact, she may be considered as a large hollow girder requiring a load of nearly 10,000 tons suspended from the centre to break her. I mention this to show that her want of success is not due to any fault in the ship herself, but to the magnitude of the speculation as a commercial transaction, and her unmanageable character in regard to the shipment of cargo, and similar difficulties which she may be called upon to encounter. I hope, however, that the necessary funds will be forthcoming to complete her equipment, and that we shall yet see her dashing aside the surge of the Atlantic at a speed of 18 to 20 knots an hour.

Railways.—The magnitude of this great Republic (as it is called) of speculation and industry is scarcely, if ever, appreciated by the public. We look at the locomotive of the present day, or glide by its means over the surface of the earth, without once thinking of the amount of skill and capital expended in the production of such vast and important results. At the present moment we learn, from returns recently published, that we have in this country alone 9500 miles of railway, executed and in actual operation, and taking at a rough calculation one locomotive engine with a force of 200 horses' power to every three miles of railway, and assuming each to run 120 miles a day, we thence calculate the distance travelled over by railway trains to be equal to 380,000 miles per diem, or the enormous distance of 138 millions of miles per annum, a space measuring the distance of the planets, and beyond the conception of those unacquainted with the measurements of the astronomer. To transport engines and trains this distance, requires a force equivalent to that of upwards of 200,000 horses in constant operation throughout the year.

As regards the commercial value of railways, it will not be necessary to enlarge upon it in this place; suffice it to observe, that a clear revenue of 12 millions is left after all expenses are paid, for distribution amongst shareholders and creditors. This amounts to 3¾ per cent. per annum, a small return upon 320 millions, the original cost of 9500 miles of railway, or an average of £34,000 per mile.

In the locomotive engine there has been no improvement of importance during the last two years, excepting only its adaptation to the burning of coal instead of coke without the production of smoke; to a certain extent this has been successfully accomplished, but the process is still far from perfect. Superior training is wanted for engineers and stokers before we can look forward with certainty to the time when the use of coal will become general, with increased economy and with the suppression of the nuisance of smoke.

In the formation of the permanent way considerable improvements have been effected, especially in the joining of the rails by what is technically termed the fish joint, which secures a more perfect union of the rails, produces a smoother surface, and diminishes the wear and tear of the rolling stock, when compared with the old system of joining so sensibly felt in carriages running over the line at great velocities.

Manufactures.—For the last twelve months great depression has existed in this department of the national industry, and, notwithstanding the attempts to cheapen the production of the staple articles of manufacture by the introduction of improved machinery, there exists a considerable depression in many of the great marts of industry. This is probably to be attributed to the disturbed state of India and China; but, looking at the activity of the manufacturing population, and the amount of capital employed, there has been no serious diminution in the production of manufactured articles, nor any stagnation in the demand for labour. On the contrary, I believe, with the exception of the causes just alluded to, that the manufactures of this country generally were never in a more flourishing condition.

In the iron trade, with which this Section is more immediately connected, there has been a similar but slight depression, the manufacture of pig, plates and bars being as great as in any former year; and, taking into account the improved process by which malleable iron and steel are now produced, there is reason to hope for a greatly increased demand and an enlarged production. In fact, such have been the improvements since Mr. Bessemer first announced his new process of boiling the crude iron direct from the smelting furnace, and dispensing with the puddling process, that we appear to be now in a state of transition from the old system of smelting, refining, and puddling, to a more direct, continuous, and improved process of manufacture.

Steel bars and plates are now made without the intervention of an intermediate and tedious process, and we may reasonably look forward to the introduction of an entirely new article of manufacture of greatly increased powers of resistance to strain. Although hitherto Mr. Bessemer has not succeeded in producing malleable iron by his new process, he has made excellent refined iron, and has stimulated others to attempts at improvement in the same direction. His discoveries, first given to the world through this Section, have already proved of great value to the community, and we look forward with confidence to the introduction of still greater improvements—improvements by which steel plates and bars will be produced at almost the same price as that for which we can now obtain the best manufactured iron.

The Machinery of Agriculture.—This is a branch of mechanical art which requires the careful consideration of the mechanician and the engineer. The time appears to have arrived when the introduction of machinery, combined with the wide diffusion of education, is absolutely required amongst our agricultural population; and in my opinion, increased intelligence, together with new machinery, will double the production of the soil and improve the climate in which we live. Much has already been done, yet very much is yet to be accomplished. We must persevere in the new process of deep draining and subsoil ploughing, and in the substitution of steam power in place of horse and manual labour, before we can realize such large and important advantages as are now before us. Great changes and improvements have been effected in my own time by the introduction of new implements to relieve the labours of the farm. Everything, cannot, however be done by the mechanician and engineer; much has yet to be accomplished by the farmer in the preparation of the land to render it suitable for machine culture, and a willing heart as well as a steady hand is required of the agriculturist before he can work for the public good in concert with the engineer. The reaping machine has now attained such a degree of perfection as to bring it into general use on lands prepared for its reception; and the steam plough is making rapid strides towards perfection, and is likely to take the place of horses, and effect a change as beneficial to the farmer as it will be advantageous to the public at large.

Electric Telegraphs.—The consummation of telegraphic communication between the old and new world is the crowning triumph of the age, and I hail in common with every lover of science the immense benefits which the successful laying of the Atlantic Cable is calculated to secure for mankind; it is another step forwards in the great march of civilization, and the time is not far distant when we shall see individuals as well as nations united in social intercourse through the medium of the slender wire and the electric current. These are blessings which the most sanguine philosophers of the past never dreamed of; they are the realizations of the age in which we live; and I have to congratulate the Section on what has already been done in the wide, and to some extent unexplored field of this wonderful discovery.

On a new Method of constructing the Permanent Way and Wheels of Railways. By W. Bridges Adams.

The object of the improvement about to be described is to obtain all the advantages of both the bridge-rail and the double T-rail, while avoiding their disadvantages; that is, the horizontal stiffness of the bridge-rail with more than the vertical stiffness of the double T-rail, with a lowered elevation, without any chairs or loose contact of iron with iron, and with the firmest joint yet produced, making the line of rails a continuous yet expansive and contractile bar, on a continuous bearing.

In this new construction the ordinary double-headed rail is not placed in chairs *on* cross sleepers, but is bolted *between* longitudinal sleepers of small scantling, which supply the place of cast chairs, by continuous wooden supports. The bolts are either ordinary screw-bolts or pieces of flat bar, with keys and washers passing through both rails and timbers at 3-feet spaces. The rail is thus supported by the upper table without resting on the lower, and the bearing surface on the timber is in a yard length equal to 54 inches, the chair in the same length being only equal to 48 inches; the former being continuous, the latter discontinuous. The bearing surface on the ballast is equal to that of the cross-sleeper rail with the sleepers 3 feet apart. The height of the rail above the ballast is only 5 inches, while that of the ordinary cross-sleeper way is 12 inches. There is, therefore, a saving of half the ballast. The rail are connected by brackets of angle-iron, which are bolted to and through both rails and brackets at the joints, the brackets being bolted down on cross sleepers at the joints; thus securing the gauge.

The advantages of the system are,—1st, a maximum depth of rail, with a minimum elevation; 2nd, a continuous bearing on timber; 3rd, great lateral stiffness; 4th, a really reversible rail without risk of damage or crystallization, with the lower table perfect, when the upper is worn out; 5th, great safety, by reason of the rail being secured without chairs and keys; 6th, diminished cost of maintenance, and rapid shifting of rails.

As to the wheel, practically, a driving wheel, at 50 miles per hour, is equivalent to a large Nasmyth's hammer, wherever any inequality exists between rails and wheel: the incessant leap of the wheel from point to point is a heavy blow.

To obviate this disadvantage, it is desirable to render the wheel elastic. The improved wheel is so constructed, that a continuous hollow in the internal periphery of the tire is overlapped by a continuous hoop-spring, on which the wheel rests in such a mode that the only dead-weight is in the tire. The tire is formed with an internal front rib; and when the wheel is forced in upon the spring by cold pressure, a false rib is fixed at the back, and the wheel is secure. The wheel thus treads on an elastic cushion all round the periphery. It cannot be strained on mischievously tight, as by shrinking hot; and the metal is in a state of rust.

The advantage in saving wear of tire is found to be considerable, and it is obvious the saving must extend to the rails also.

The commercial advantages are considerable. In the permanent way the cost of the whole of the chairs is saved, and a portion of the timber, while the fastenings are about the same cost in either case. The saving of labour, and heating, and tools in the construction of the wheels is considerable; and the quantity of material is diminished. Both permanent way and wheels have now been a considerable time in practical use, which is extending as the system becomes known.

On a few Facts connected with the Manufacture of Pig Iron in the neighbourhood of Leeds. By W. J. ARMITAGE.

The author first quoted an extract from the 'Geological Survey,' in reference to the peculiarities of the coal-fields of Yorkshire, and then proceeded to point out the position occupied by the valuable seam of coal in the districts of Bradford and Leeds. The superficial seams of coals worked in the immediate neighbourhood of Leeds he gave in the various orders in which they occur:—

1st. The stone or cannel bed. 2nd. The Middleton bed.
3rd. The Beeston thin bed. 4th. The Beeston thick bed.
5th. The Crow coal.

Below the latter seam, that portion of the strata especially connected with the manufacture of iron in the North Yorkshire district was arrived at. A section of this part of the strata gave the following results:—

1st. Loose vein of sandstone, 9 to 18 feet thick.
2nd. Black bed ironstone, lying in a bed of shale, 3 to 4 feet thick.
3rd. Black bed coal, 2 feet thick.
4th. Various measures of shale and stone, roof of better bed coal, consisting of black shale, with numerous fish remains, and small white nodules of ironstone, 120 feet.
5th. Better bed coal, 1 to 2 feet.
6th. Floor of indurated fire-clay, 2 to 3 feet.

From this portion of the strata, comprised within the short space of forty yards, the materials employed in the manufacture of the iron were derived. The black bed ironstone furnished the ore, the better bed coal the fuel, the black bed was used for the engines, and from the valuable bed of fire-clay were made the fire-bricks and blast-furnace linings. The ironstone occurred in detached nodules of various sizes, deposited in five distinct layers, which were designated top balls, flat stone, upper rough measure, middle balls, and lower rough measure. In some localities their course was difficult to trace in the surrounding shale; in others, where the seam was termed good, the ore produced 1000 tons of stone per acre, and this was about the average yield at Farnley. The fracture of this stone showed a blackish grey tint, and yielded by analysis—

Metallic iron	39·4 per cent.
Silica and alumina	14·9 per cent.
Sulphur	·8 per cent.
Oxygen, carbonic acid, &c.	44·9 per cent.

A singular affinity seems to exist between the ore and the better bed coal in this district. The results obtained from other descriptions of stone have not been satisfactory. With respect to the fuel employed, the better bed coal burnt free from sulphur, and, as this was one of the chief obstacles in the manufacture of iron in this country, such a coal was a great desideratum. Mr. Wood, of Leeds, had lately analysed one sample of this coal, and the following were the results:—

Carbon	74·700
Hydrogen	5·000
Sulphur	·196 (very small).
Ash	4·700
Oxygen and nitrogen	15·404
	100·000

Other analyses would have to be made on different samples of the coal before the average amount of sulphur could be determined with precision, but this first essay was satisfactory, inasmuch as it placed the better bed coal of this district in the foremost rank amongst the pure coals of England; and it was to the excellence of this fuel, as observed in the memoir of the Geological Survey already referred to, that the good quality of the iron manufactured at Low Moor, Bowling, and Farnley, was mainly attributable. In conclusion, he referred to the points of importance in connexion with the process of refining the pig metal at the Farnley Iron Works, which were peculiar to that establishment. The first had reference to the introduction of steam into the refinery along with the blast; the second was the introduction of steel into the refineries in conjunction with the pig metal. The refined metal thus produced presented a pure silvery fracture, and a perfectly homogeneous texture.

On Steam Tugs employed on the Aire and Calder Navigation. *By* W. H. Bartholomew, *M.I.C.E.*

The navigation to which the subject matter of this paper refers is a combination of natural and artificial: throughout it has a *navigable* depth of 7 feet. The canals, or artificial portion, have bottom and surface widths respectively of 25 to 30 feet, and 60 to 66 feet; the sectional area of water-way varying from 350 to 380 superficial feet. The locks, which occur at varying distances of from 9 to 2 miles, admit vessels of dimensions not exceeding 64 feet long and 18 feet beam.

An improved system of haulage was introduced in 1853 by the construction of a steam tug (which had been followed by several others), designed with the combined object of providing motive power for a train of boats and capability for carriage of cargo. These tugs were in length 63 feet 6 inches, having beam respectively of 11 feet and 12 feet 6 inches, depth of hold 7 feet 3 inches, immersed midship sections 64 and 72 square feet respectively, displacement with such immersion 40 tons for cargo, and 8 to 10 tons for machinery and stores. The engines and boilers were fixed in the after portion of the boats, and occupied 20 feet of their length; and 30 feet were devoted to cargo and 12 feet 6 inches to accommodation for the crew. The remainder of the length was taken up by bulkheads, stores, &c. The peculiar machinery of these boats was next illustrated by a technical description and plans; and the author then proceeded to show that by a new arrangement of the screw, adopted in other more recent tugs, there was a considerably lower per-centage of "slip." This screw consisted of two ordinary screws fixed on the same shaft at right angles, or otherwise, to each other, having an intervening space of six or more inches between them, and consequently their planes of rotation were different; their pitches also varied, the after screw having the greater. This application had proved to be most successful. In working these tugs the pressure of steam was regulated to the duty to be performed, and had varied from 100 lbs. to 220 lbs., but did not often exceed 160 lbs. per square inch. The general speed of the engines was 180 revolutions, or 360 feet speed of piston per minute. This speed of piston, when working at full pressure, gave 100 effective horse-power for the larger, and 50 horse-power for tugs of less power. The former, under such circumstances, took a load of 500 tons of cargo, or a gross load of 650 tons at a speed of 3 miles per hour in the canals and $4\frac{1}{8}$ miles in the river portion of the navigation. The latter hauled a load of 220 tons of cargo, or a gross load of 325 tons at the same speed in the canals, and $3\frac{3}{4}$ miles per hour in the river. On an experiment with one of the more powerful tugs, twelve vessels, containing with the cargo in the tug 832 tons, or a gross tonnage moved of 1222 tons, were taken in the river portion of the navigation a distance of $4\frac{1}{2}$ miles in $1\frac{1}{2}$ hour, or, allowing for current, $2\frac{1}{2}$ miles per hour. On another occasion the same tug took nine vessels, containing with the tug 552 tons of cargo, or 852 tons gross, over the same portion of the river (allowing for current), a speed of 4·87 miles per hour. The dynamical effect on the tow-rope in the former case varied from 28 to 34 cwt., and in the latter averaged about $27\frac{1}{2}$ cwt. These tugs were also very useful for breaking up and contending against ice; and there was also a diminished consumption of fuel as compared with the previous tugs employed,—which were paddle-boats. The commercial results were as follows:—*9d.* per boat per mile by the paddle tugs; *7d.* by horse haulage, &c.; and 4·15*d.* by screw tugs. The economic proportionals were consequently 1, 1·68 and 2·15. The trip of 36 miles was thereby accelerated two hours, and increased certainty was obtained.

Description of a Floating Dry Dock. By G. BAYLEY.

The dock in question was designed in 1836 for a South American Government; it was intended to be moored in deep water, and ride with a ship of war in it with safety during ordinary gales.

The port, or rather open roadstead, in which it was proposed to place the floating dock, had a rise of tide of about 6 feet. To meet the peculiarities of the place, it was proposed to construct the dock so that it could be immersed or sunk down to any depth that might be required to admit the ships of various classes, and be strong enough to ride with them, without straining the ship.

Three things had to be combined—strength, rigidity, and buoyancy. The needful strength and rigidity were to be secured by a very simple system of bracing and trussing, and the whole framing covered with planking well secured and made water-tight. This space was subdivided longitudinally and transversely, so as to obviate any risk from the rushing of the water from side to side or from end to end of the dock; and at the same time, these longitudinal and transverse partitions would add to the strength and rigidity of the entire fabric.

A transverse section of the dock would show that the floor of the dock is a framed beam, consisting of two tie pieces about 4 feet apart, with queen posts in the centre, under the ground or lower tier of keel blocks, with tie bolts introduced where necessary. The sectional area must be proportioned to the entire weight of the dock with the ship, so that, if desired, it may float with its upper internal surface above the level of its external waters. The angular or rectangular space between the outer and inner planking of the sides must be of sufficient volume to allow the dock to be sunk to any required depth to receive the ship.

The dock itself must be ballasted with sufficient weight to render it specifically heavier than water, in order that it may be readily sunk to the required depth.

It was proposed to have an engine fixed on the deck forward, to pump out the water from the subdivisions, and also to drive saws and any other tools required for carrying on the repairs*.

It would be desirable to construct such docks of iron, which is peculiarly suited to meet all the requirements of such structures as to strength, rigidity, and buoyancy, at less cost than timber under almost every combination of circumstances.

The peculiar advantage of the kind of dock now suggested is its adaptation to places, where, from local circumstances, it is difficult, if not impossible, to build secure and substantial dry docks on the shore.

* The paper was illustrated by a model, showing the general construction and proposed arrangement of the engine, pump, &c.

On an Instrument for describing Spirals. *By the* Rev. James Booth, *LL.D., F.R.S.*

This is the invention of Mr. Henry Johnson of Crutched Friars, and is called by him a volutor, with reference to its practical use.

It admits of several varieties; and the earliest form affords a simple illustration of the principle of the spiral line,—that is, of a line revolving round a point at one end, as round a centre, while a marking point travels, during the revolution, from the inner end or centre to the outer end of the line. It consists of a vertical axis resting on a horizontal plane, and retained on it by a metal point to prevent slipping or lateral motion. To this upright axis is attached one extremity of the horizontal arm or bar. The vertical axis passes through the extreme end of the horizontal arm, or a block attached to the end of it, in such a way that the horizontal arm may freely revolve round the vertical axis. The remote extremity of the horizontal bar is furnished with a drum or pulley, over which a chain or band passes.

One end of this band is fixed to the centre upon a level with the pulley; and the other end of the chain or band, after passing over the pulley at the outer end of the horizontal rod, returns and is fastened to a slide upon the horizontal bar, which carries a pencil or pen, and is placed at the inner extremity of the bar, close to the vertical axis.

The horizontal bar is caused to revolve; and the band is thus wound round the centre, and the slide, with its pencil, is drawn along the bar from the centre towards the pulley,—the spiral curve traced upon the horizontal plane by the pencil being the result of the compound motion of the point travelling along the revolving line. The form of the centre, if cylindrical, would lead to a regular increase in the radius of the spiral; but by the substitution of grooved cones, any required ratio of increase may be obtained.

A recent form of the instrument is even more simple than the one described,—the slide being dispensed with, and the pencil being attached to the horizontal bar, which glides through a horizontal tube fixed to the lower part of the vertical centre. The upper part of the vertical centre being a cone, with its handle is held stationary by the hand, while motion is given to the lower part with the horizontal tube by a small winch handle fixed on a wire descending through the cone and its handle. The end of the bar bearing the marking pencil recedes from the centre as the outer end is drawn towards the centre by the band wound round the vertical axis.

To the horizontal tube and to the outer end of the bar are attached series of pulleys; and a variety of curves may be obtained by passing the band over two or more pulleys, and thus dividing among several lines the effect of the band wound round the centre.

On the Roof of the New Town Hall at Leeds. *By* C. Brodrick, *Architect.*

The principal points which are worthy of notice in this roof are the absence of tie beams, which allows of the ceiling of the hall being brought nearer to the exterior of the roof than is usually the case. The roof consists of eight sets of principals framed together. Each principal consists of a semicircular laminated rib, formed of twelve 1½-inch planks, 9 inches wide, nailed together and fastened with wrought iron bolts and straps. They are placed in couples, and stand immediately over each of the columns in the hall. They are respectively 4 feet and 18 feet apart. The width of the room is 71 feet, and the springing of the ribs 53 feet from the ground. The entire height to the top of the roof is 99 feet, the hall being 73 feet high in the clere. This system of roofs has been adopted more frequently in France than in England, the only one with which Mr. B. was acquainted of any considerable size being the station of the Great Northern Railway, at King's Cross. The laminated rib is the invention of a French engineer. It was at first suggested for a bridge over the Rhine, in the year 1811. Several years later, M. Emy constructed several roofs on this plan; but all his roofs, as well as the one at King's Cross, being very near to the ground at their springing, and without ceilings, are consequently much more manageable than the roof of the Town Hall, which has a very elaborate plaster ceiling attached to it, and the springing is at a considerable distance from the ground: he had taken the precaution to insert several additional struts and braces as a preventive against any change of form or outward thrust. Both these points had been attended with the most complete success, there being not the least perceptible outward thrust or change of form since they were put up. The latter fact was proved very satisfactorily by the plasterers, who were enabled to run the mouldings on the ceiling from the centre. The brackets for these mouldings were not gauged from a centre, but fastened to the ribs according to their sizes. In constructing these semicircular ribs, he was much struck with the small amount of springing or alteration of form. If the principle of these laminative ribs were better understood, he was of opinion that many of our church-building architects would adopt it, instead of depending on three or four over-strained joints for one tie.

Notice of some of the Articles shown in the Mechanical Section of the Leeds Exhibition of Local Industry. By J. Buckton.

The following are some of the chief articles exhibited:—

A fine collection of malleable iron, boiler plates, and angle-iron as used in ship-building, locomotive crank and other axles, and wheel tires in various forms.

A model of a weighing crane, designed for raising and weighing heavy goods at one operation.

Naylor's double steam hammer. A collection of engineers' tools.

A lathe for turning irregularly-formed pieces of wood, and an endless tape-saw; also the adaptation of Comb's expanding pulley to a drilling machine.

Kemp's woollen cloth dressing machinery.

Taylor's corn mill, with the upper stone stationary and the lower one revolving. The stones are 2 feet 8 inches and 3 feet in diameter, weighing 3 cwt. to 5 cwt. each, versus 15 cwt. to 20 cwt., the weight of ordinary millstones. The work is found to be done much more effectually, at a reduced cost of masonry and building.

Carrett, Marshall, and Co. stationary pumping and other engines.

Comb's and Smallpage's new double cam power-loom. In this power-loom all the movements for plain weaving are obtained from one shaft perfectly balanced in itself and revolving at half the speed of the crank shaft of the old loom. In the shuttle used in the loom, the weft is packed into the shuttle in the form of a hollow roll, and drawn from the internal surface.

Holmes' loom for working ladies' corsets without a seam; it differs from the ordinary way of weaving, by the yarn being on several pulleys in small quantities, instead of all being on one beam.

Miller's card-setting machine.

Haste's new self-acting apparatus for preventing the explosion of steam boilers.

A working model of Donnisthorpe's wool-combing machine.

On some modern Appliances for Raising Water. By W. E. Carrett.

The author, after alluding to the various kinds of pumps in use, proceeds to describe two combinations of the *steam engine* and *pump* in direct action. In each case the steam cylinder is directly over and in immediate communication with the pump beneath. A comparatively slight transposition of detail would arrange these horizontally, if required. The first described was a steam pump of the high pressure transportable class, having a fly wheel and connecting rods to the crank shaft; also a modification of this for especial cases, where lightness and portability are requisite: the other was a compound high and low pressure condensing steam engine, also in direct communication with its pump, and of much larger proportions, used as a water-lift.

The chief object in view is simplicity and durability of parts, a quiet and noiseless action, and, as far as possible, a superior duty effected with a minimum expenditure of power. One important feature to be observed is the application of the suctional and compressive air vessels in close proximity to the pumps, by which it is able to fetch the water from any distance (of course within the limits determined by the friction in the pipes), or from a depth not exceeding 29 feet, and to force it any required height or distance.

The author then, by the aid of diagrams, explained these several machines.

Some Account of Lewis Paul *and his Invention of the Machine for Spinning Cotton and Wool by Rollers, and his claim to such invention, to the exclusion of* John Wyatt. *By* ROBERT COLE, *F.S.A.*

On an Apparatus for laying down Submarine Telegraphic Cables. By H. CONYBEARE, *C.E.*

This invention consists in the construction of machinery composed of a resilient and articulated series of segments or frames, which extend from the stern of a vessel employed in the submerging of submarine telegraph cables, and over which machine the cable is to be paid out, being delivered from a trumpet-mouth shaped congeries of friction rollers, situated at the outer extremity of the frame furthest from the stern, in which machinery the resiliency decreases gradually from that part of the apparatus next to the stern, to the extreme outer end thereof. The articulated joints or segments of the apparatus are formed of frames, each frame, starting from the stern, being smaller than that supporting it. Strong springs, such as coach-springs, fixed to one frame and linked to the farther extremity of the vessel, are employed to give resiliency to the articulations between each frame and that next to it, and the frame furthest from the stern terminates in a semi-conoidal or trumpet-mouth shaped debouchure, consisting of rings of friction rollers breaking joint with each other, and so arranged as to present a rolling surface of moderate curvature to the escaping cable, at whatever angle with the course of the ship it is compelled by side currents or lee way to quit the apparatus.

Over this resilient and articulated series of frames is a rigid spur of wood or metal, having suspended from it, outward, as many pulleys as there are joints in the apparatus last described. An equal number of pulleys is provided inboard. A rope or chain is connected to the extremity furthest from the stave of each joint, then to a spring, or not, as deemed necessary; and then, passing over one of the outboard pulleys and one of the inboard, in the rigid beam is attached to a spring apparatus, so arranged as to give a resiliency graduated according to the position of such particular piece in the series.

This spring apparatus consists of a series of wheels and axles. The resilient springs act on the axles in each case, and the ropes or chains leading to the various parts of the laying apparatus are attached to the wheels. The ratio of the diameter of the wheel to the axle varies in each case, according to the amount of resiliency required by the particular joint or frame of the fishing-rod apparatus, with which such wheel and axle are connected. Thus, as the delivery extremity of the apparatus is required to be moved through a comparatively large space by the exertion of a comparatively small strain, the ratio of the wheel to the axle in the resilient apparatus pertaining to this end frame is consequently greater than in that pertaining to any of the frames nearer the stern; and thus a graduated resilience is obtained.

On Expanding Pulleys. By Mr. COOMBE.

This paper has been prepared at the request of Mr. Fairbairn, the President of the Section, the pulley itself having been carefully examined by Prince Albert at the time of his visit to the Exhibition of Local Industry, and by him warmly approved. A pretty correct idea of these pulleys may be formed by supposing two cones cut with radial spaces alternating with solid parts, so that the solid parts in one may slide freely into corresponding spaces in the other, in the direction of a common axis. The sizes of these radial sections are so regulated, that when the two cones are put together they form a grooved or V-pulley, the diameter of which varies according to the position they occupy with regard to each other. The expanding pulleys were first designed for the purpose of giving the varying motion to the bobbins in flax and tow roving frames, to which it is applicable with great advantage from the accuracy of its action and the small space which it occupies.

On Reaping Machinery. By ALFRED CROSSKILL, *of Beverley.*

After alluding to a paper read on this subject in the year 1853, which contained an account of all the inventions for reaping upon record up to that time, Mr. Crosskill stated that there were then three reaping machines capable of doing practical work: the two American reapers known as Hussey's and McCormack's, which came over to the Great Exhibition of 1851; and the Scotch machine called Bell's (after its originator, a minister in Fifeshire), which was brought into general notice, and subsequently into practical operation, by Mr. William Crosskill, of Beverley. Since the year 1853 these three machines have been greatly improved, to adapt them to the requirements of British agriculture; Hussey's by Messrs. W. Dray and Co., McCormack's by Messrs. Burgess and Key, and Bell's at Beverley, under the direction of the reader of the paper; and, by means of numerous working models and drawings, the construction and peculiarities of these three machines were fully explained and illustrated. With reference to the cutting apparatus, it was remarked that numerous endeavours have been made from time to time to supersede the reciprocating motion given to the knives of the reaper, as it is a considerable source of loss of power, and causes a tremulous vibration, resulting in excessive wear and tear. All attempts have, however, hitherto failed to produce an efficient cutter, with a continuous motion, and in his (Mr. Crosskill's) opinion they were not likely to succeed, as actual experience in the harvest field seemed to prove that the reciprocating or reverse motion is necessary to prevent the guards and knives from being choked with short straw, grass, weeds, and similar substances. The convenient disposal or delivery of the cut corn has been the greatest difficulty to encounter in bringing the reapers into general use in this country. Two of them are, however, made to deliver the crop in swathes, ready for taking up and binding; and from the third the corn is removed in sheaves by a man who rides on the machine. Various ingenious plans have from time to time been brought forward for delivering the cut corn. Of these an excellent model, from Messrs. Ransome and Sims, Ipswich, was exhibited of Atkin's automaton self-acting rake, and a description given of the Britannia reaper, which was sent over from America this summer, to Mr. Samuelson, of Banbury. The different methods of attaching the horses, either by making them follow the machine, or walking by the side of the corn to be cut, were fully pointed out, and the advantages of each plan stated in detail. Makers and users of reaping machines are divided in opinion as to which is the best way; both have many warm advocates, and will probably continue to be used according to the different circumstances under which the machines are employed. In offering some remarks on the practical use of reaping machinery, Mr. Crosskill said it was necessary to direct attention to the variable and uncertain nature of the work it has to perform. A week of heavy rain before harvest will lay the corn in some districts so that it can scarcely be mown with the scythe, and is rendered quite unfit for the action of machinery; in moderately favourable seasons, however, the reapers, as at present constructed, are capable of rendering important assistance to the farmer. The use of both reaping machines with self-acting delivery is steadily extending, and, as agriculturists and their men become more accustomed to them, their introduction is likely to become still more rapid, for, owing to the high price of labour during the harvest, they effect a considerable saving in the cost of cutting the crop, and enable the farmer to take more advantage of favourable weather than he can do by the uncertain aid of the limited number of men that are to be procured at that period of the year. It was also worthy of a remark in connexion with this part of the subject, that, excepting the locomotive engine, there is no machine in use which requires to be manufactured with so much care and regard to durability as the reaper. Almost all other machines used either in agriculture or manufactures do their work when at rest, and secured to substantial foundations. Even those constructed to move from place to place are, before being put in motion, fastened down, to prevent as far as possible the destructive consequences of oscillation and vibration. The reaper is, on the contrary, not only exposed to all the strains consequent on passing over every description of uneven ground with its machinery in action, but is also subject to the effects of a continual tremulous vibration, caused by the quick reciprocating motion of the knives. It was therefore not surprising that the introduction of reaping machines has been attended with considerable difficulties, especially as they have had to be worked by men but little accustomed to the use of machinery; in this respect, however, the last few years had witnessed a great change. The assistance of the steam-engine was already felt by most farmers to be a necessity in carrying out all extensive operations with efficiency and economy;

and the general use of improved machinery would not fail to produce a corresponding improvement in the condition of the agricultural labourer, and to accelerate the completion of that progressive revolution, which, since the abrogation of legislative protection, has been rapidly taking place in every department of practical agriculture.

On Double Cylinder Expansion Marine Engines. *By* J. Elder.

These engines are constructed with the view of getting the greatest amount of power from a given quantity of steam at a given pressure, with less total weight of engines, boilers, and water, and occupying less total space than that occupied by the ordinary class of steam engines on board steam-ships; these engines are therefore expected to have the following properties:—

1.—That with these engines a steam-ship can steam the greatest distance possible with a given quantity of coals.

2.—That a given distance can be performed in the shortest time, on account of the small weight of coals necessary to be carried.

3.—That the greatest amount of cargo and passenger accommodation is obtained, from the small room occupied by the boilers and coals.

4.—That where a given capacity of cargo and passenger accommodation is required, a smaller and consequently less expensive ship is necessary.

5.—The boilers, being less than the usual proportion, are less expensive to replace when required.

6.—The number of firemen and stokers is reduced, and, consequently, the space occupied by them can be otherwise engaged, and their wages saved.

To accomplish these objects, the constructors of these engines have followed the course we now describe. The cylinder capacity is so great as to admit of the steam being expanded to within two pounds of the pressure in the condenser, at the end of the stroke, while the engines are working full power. In order to reduce the shock of high pressure on such a large piston, a cylinder with a piston one third the size is placed close to it. This small cylinder receives the steam direct from the boiler during one-third of its stroke, and is then cut off; this steam is consequently reduced to one-third of its original pressure at the end of its stroke, and then enters the second cylinder, where it is expanded three times more: thus 36lbs. steam is expanded to 4lbs., viz. from 36 to 12 in the first, it then enters the second at 12 and is expanded to 4lbs.; but, as the second piston is three times the size of the first, the load will be the same on both pistons, and the piston rods, cross heads, and connexion rods may be duplicates of each other. The steam and eduction slide valves are wrought with eccentrics. The steam valve is a gridiron with large flap; the eduction valve, which serves for both cylinders, has no lap, and the eduction ports remain open during the entire stroke of the piston, thereby giving a free egress for the steam, and ample escape for water, should it form.

In reversing the engines the eccentrics are made to overrun the shaft till they arrive at the backing catch—a plan which is less likely to cause accident than the ordinary methods. The cylinders are steam-jacketed completely, and then covered with felt and wood. There is a small engine pump for forcing the distilled fresh water from the jackets into the boilers, or to the fresh-water tanks, if necessary.

The boilers now being made for such engines are tubular, with three large superheating uptakes, 2 feet in diameter and 15 feet high, leading up through an oval steam chest to the funnel; this makes a strong form of take-up, where it joins the tube plate, especially in boilers firing across the ship. The feed-pipe of the boilers has twelve spiral convolutions inside the funnel to heat the feed-water. This may be shut off when desirable.

The author then mentions the various vessels in which these engines have been fitted, and shows by comparison with other engines the great saving of expense, combined with greater efficiency.

A Description of a Hand Heliostat. *By* F. Galton, *S.G.S.*

By this simple instrument the rays of the sun could be flashed with ease and precision upon any required spot. The appearance it produced was that of a brilliant and glistering star, and its power was sufficient to arrest the notice of the most careless person at ten miles' distance. No sky line was necessary to the distinctness of this remarkable signal, as is the case with semaphores and flags; indeed it was visible to the greatest advantage in front of a dark or hazy background. It could be used with equal facility from any spot where the sun's rays reached it, as from between the trees of a forest or from a boat, as well as from a mast-head or a hill-top. It had another peculiarity, in being enabled to flash its messages in perfect secrecy, except to those who happened to be stationed in the narrow path along which they were sent. Many occasions would arise, especially in war time, where this invention would be of use. If the signaller was ignorant of the whereabouts of his correspondent, he must sweep the horizon with his flash until it had been seen, and a response elicited. For a more detailed description of this instrument, see the Proceedings of Section A.

On the Economy of Water-Power. *By* JOSEPH GLYNN, *F.R.S.*

In this part of England, and in other manufacturing districts where coal is found, the steam engine will generally be preferred to all other kinds of motive power; but in many parts of the British empire, more especially in Scotland and Ireland, coal is scarce and water is abundant, and is now too often allowed to run to waste where its application to turn mills and to work machinery for farming purposes might save both time and money.

Those machines produced at the Paris Exhibition, to which the writer would more particularly allude, are the horizontal water-wheels, some of which were wrongly named Turbines, whereas they were really substitutes for the machines so called.

The Turbine is a machine of re-action, from which the water issues in jets, and the unbalanced pressure opposite the orifice impels the machine and causes it to revolve in the opposite direction. It requires considerable skill in its construction, and careful attention when in use; but the horizontal water-wheel is a much more simple machine, and much less liable to derangement. The water drives round a fan with curved vanes, having a vertical axis and revolving in an iron case, the water escaping at the centre.

The horizontal water-wheels in the French Exhibition consisted of two parts, or wheels, placed horizontally on a vertical axis, one wheel immediately above the other. The upper part or wheel is fixed, and serves to direct the water into the buckets of the lower one,—that is to say, the real water-wheel,—which revolves, and the axle or spindle revolves with it.

The regulators, which determine the quantity of water and the speed of the wheel, may vary in almost every instance, some being mere wooden sluices, some being metal plates pierced with apertures like a ventilator, and some of stout leather strengthened with iron plates, fitting on conical rollers and radiating from the axis. Some of these wheels are very powerful, and carry a spur-wheel upon the vertical axis, surrounded by six pairs of millstones for grinding corn, driven by pinions in the usual way; other wheels, of smaller size and greater speed, drive a single pair of millstones, without the intervention of other mechanism, the axis of the water wheel being also the spindle of the mill-stone.

The mechanical effect of these machines, when carefully made, is said to equal that of an over-shot or breast wheel. Some realize 75 per cent.

On the Cause of Steam-boiler Explosions, and Means of Prevention. *By* J. HOPKINSON.

The author in this paper shows the necessity of increased attention to the form and construction of steam boilers. After noticing the hay-stack, waggon, Cornish, and Butterly boilers, he very fully describes the want of safety in the double fire-box boiler, and states the various causes of boiler explosions. He then says: "I now propose to show you the patent compound safety-valve, which is a prevention against explosions from the causes before enumerated, and the explosions which have taken place from all causes excepting that of a defective boiler, as under all other circumstances steam boiler explosions are rendered impossible."

The patent compound safety-valve comprises two distinct valves, a large 5½ inch diameter valve with flat face and a spherical or ball-faced valve 3 inches in diameter;

the smaller or ball valve sits upon the centre of the larger one. The larger valve is weighted by means of a lever and ball, as in the common safety-valve; there is an iron bridge or cover casting, which fits to the large valve and forms the centre for the centre pin to give pressure upon the valve enclosed: and resting upon the centre of the large valve is the ball valve, which is weighted by a dead-weight inside the boiler, the dead weight being comprised of iron plate castings. When the steam exceeds the pressure this ball-valve is weighted to, it escapes through the openings in the bridge casting into the dome or shell and out into the atmosphere. As soon as the ball-valve lifts from its seat, the large one also lifts from its seat; and thus a double discharge is given to the excessive steam. The feature here presented is of importance, inasmuch as we find a valve possessing an opening or discharging area equal to an ordinary safety-valve 8½ inches diameter. The valve cannot be weighted beyond its working pressure whilst the boiler is at work, as it will be seen; should an attempt be made to weight the lever or even press upon it with all force, that would be useless so long as the ball-valve was there; and even should the ball-valve be weighted intentionally whilst the boiler is standing for cleaning, &c., it may instantly be detected by placing the ball on the lever in its ordinary working place; and by getting up the steam you will discover such tamperings and to what extent, by the marks on the lever. Yet when the boiler is at work it defies any tamperings.

With respect to its improved arrangement for deficiency of water,—there is a lever suspended in the boiler; the rod which bears the weight for the ball-valve passes through a large hole in the centre of this lever. On this rod is fixed a collar, which is arranged so as to allow the lugs of the lever to come in contact with it as before mentioned. There is a lever or beam suspended in the boiler, one end of which bears a large float, the opposite end a balance weight, to counteract the buoyancy of the float when immersed in the water, and to keep the lip of the lever up against the under side of the top of the boiler; the float is immersed in the water to such a depth as is called low water mark. When the water begins to leave the float, the specific gravity of the float is then brought upon the end of the lever, which turns upon a centre; the lugs then are brought into contact with the collar on the rod, and the valve is raised from its seat.

Should the water still get lower, the valve continues to rise, and will do so until the water be again at its proper height: should the warning be disregarded, the steam will all be discharged from the boiler and stop all working, and render explosion impossible.

On the Drainage of the Metropolis. *By* E. Jones.

The author proposes to place portable tanks within cesspools constructed in the sewers, each capable of holding about one ton weight of solid sewage matter. A bar or grating to be fixed within the sewer, at one side of the tank, so constructed as to act as a coarse filter to check the solids which will then be precipitated into the tanks. The tanks when full to be lifted out by a portable crane, a lid being first securely fixed thereon, so as to prevent the escape of the least smell. Previous to the act of removal the communication with the sewers will be cut off, by doors or flood-gates, made to slide in a grooved frame, by which the water in the sewer will be arrested and the effluvia prevented from escaping into the streets during the removal. The author suggests that a series of these tanks be placed at a quarter of a mile distant from each other within the sewers, and that thus the drains could beeffectually scoured. He estimates that the cost would not exceed one and a half million: also, that the Thames should be embanked; within which embankment it is proposed to construct, at the end of each main sewer, three reservoirs, to be divided into compartments and fitted with moveable tanks to collect the sediment produced by deodorizing with lime. Ornamental chimney shafts with furnaces to be constructed near the mouths of the main sewers for the purpose of drawing off the noxious gases, and also for the purpose of consuming refuse vegetable matter. The resulting ashes may be used for deodorizing the sewage.

On the Application of Mechanical Power to the Bellows of Organs. *By* D. Joy.

To work the feeders of an organ, a reciprocating motion alone is required; but it must be capable of perfect regulation down to an infinitesimally slow speed, and without impairing its certainty of action at that slow speed. Hence it cannot depend upon momentum to pass the dead points at the top and bottom of the stroke, as in a steam engine; and for simplicity it must only consist of one cylinder. It must also be absolutely independent of attention or lubrication, and be always ready for use.

The author, after detailing the results of a number of experiments, described an engine which he illustrated with drawings. For some time the engine continued to work perfectly; but afterwards difficulty was experienced in lubricating the valve upon its face, this requiring attention varying from once per month to once in three or six months. Various metals were tried relatively for the valve and face; but all after a time squeezed out the lubricating material from between them, and cut into each other. Glass was tried with no better success. Lastly, a lignum vitæ valve was put in: this stood every test, and, though taking a little more power to drive when originally put in, it was found to need no lubrication of any kind, the water acting in the place of it.

The peculiarities of the engine as it now stands are—1st. A machine giving out a reciprocating motion by the pressure of a non-elastic fluid, and capable of being regulated to the lowest possible speed without the possibility of failing at the return stroke, that return stroke depending upon a movement completed by the previous stroke. 2nd. The adaptability of this machine to work under any pressure of the afore-named non-elastic fluid, entirely free from the shocks usually attending such machines from the necessity of suddenly changing the direction of the moving column, which may be changed as slowly as requisite, by retarding the valve, or diminishing the outlet. 3rd. The entire independence of attention or lubrication.

The organ of the Leeds Town Hall is blown by five of these engines. They are calculated to be able to supply 50 cubic feet of air per second, at a pressure equal to a column of water of 6 inches, and when working at full speed to develope a power equal to about 8 horses, as calculated by Watt's rule.

On the Application of Combustible Compounds to be used in War. *By* JOHN MACKINTOSH.

This paper relates to the use of coal-tar, naphtha, or other hydro-carbons, alone or in combination with other materials, to be used as an agent in attack and defence; also to the application of hydro-carbons mixed with gunpowder, and brought to a plastic state by means of Indian rubber or other gums, and fibrous materials, introduced into shells and other missiles; also in filling shells with coal-tar, naphtha containing potassium, for igniting when used in water, and in filling shells with coal-tar, naphtha mixed with phosphorus and bisulphuret of carbon, with bursting powder sufficient to open the shells.

To attack fortresses from seaward, the author would generate an artificial dense and dark fog, capable of being prolonged at pleasure, in front of the batteries to be attacked, which would render them untenable, enabling the attacking vessels to approach and destroy the works unmolested by any hostile fire.

The diaphragm shells filled with naphtha, phosphorus, and bisulphuret of carbon, may be used with great effect against cavalry and troops, as the bursting of the shell scatters the contents in all directions.

When a shell containing the combustible material bursts in earthworks, the earth, being porous and incombustible, prevents the combustion from spreading rapidly, but allows the black vapour to ooze out gradually, causing most serious annoyance to the enemy, who are unable to extinguish the suffocating fog, and are hindered from carrying on their operations.

It may be brought to bear with most satisfactory results against an enemy encamped in tents.

On Constructing and Laying Telegraph Cables. *By* JOHN MACKINTOSH.

In the ordinary process of expressing the gutta percha through dies in a fluid state, the covered wire, as it issues from the die, is caused to pass into a long trough containing water, for the purpose of setting it, but great difficulty is found in causing the perfect union of the different coatings, which renders the insulation liable to leakage. In order to obviate this difficulty, the wire is coated with gutta percha by means of rollers mounted on parallel axes, and revolving in contact with each other. Each of these rollers is grooved in its periphery, and these grooves meet to form an eye, the sizes of the covering desired. Against these rollers are placed hoppers, in which gutta percha or Indian rubber is placed, in the state in which it comes from the masticator. This Indian rubber or gutta percha enters and fills up the grooves of the rollers; and where they come together, the gutta percha or India rubber in the grooves is brought together in one piece enclosing the conducting wire. The longitudinal strength and obtension are obtained by imbedding fibres of hemp, flax, or cotton in an outer layer of insulating material; this is done with great pressure. The covering is subsequently subjected to treatment which enables it to resist tropical heat, and affords quite sufficient protection against ill usage. The shore ends of the cable, or for shallow water, are protected with strong wire. In place of sulphuric acid, Mr. Mackintosh recommends the use of chloride of sulphur, mixed with a solvent by sulphuret of carbon. Add to this from 2 to 4 per cent. of chloride of sulphur, and then pass the wire through it. The speed at which the covered wire passes through the liquid is so regulated as to allow of its remaining therein for about three seconds, and this process closes up the pores thoroughly, and renders the wire much less likely to be injured by heat or abrasion. The method of submerging cables prepared by the author was to pass them through an apparatus containing water and hard-wood balls, which would allow of the accomplishment of the work without injuring the electrical condition of the ropes.

On the Submersion of Electric Cables. By J. MACLEAN.

The author proposes a plan stated to possess the following advantages:—

1. That any amount of slackable cable, from a few feet to several hundred feet, might be obtained by adopting the plan proposed, so as to meet the pitching of the vessel in a heavy sea, or any sudden stoppage in the paying-out machinery.

2. By conducting a lever, upon which the spiral springs impinge, to the paying-out machine, the rate at which the cable ought to be paid-out might be self-regulated.

3. Or this lever might have an indicator such as a dial-plate, by which the person who superintends the paying-out machine could see that a strain is upon the cable, and that more is instantly wanted;—the slackable cable in the apparatus giving him time to accelerate his machine, before the strain reaches a fixed point.

4. The plan might be wrought nearly as well with the apparatus lying in a horizontal position,—of course allowing the compensation weights to work perpendicularly.

5. The strain upon a cable, equal to one ton each mile, could never, under ordinary circumstances, by the plan proposed, exceed 3000 lbs., which is only one half of the strain caused by the pitching of the vessel during the late experiments in the Bay of Biscay.

6. By passing the cable under and over grooved wheels, an amount of friction would be created, which might be an advantage rather than a disadvantage; because, in the late experiment, it was found that the cable ran too swiftly, and that it was necessary to apply breaks. By adopting the plan described above, the increasing and decreasing friction, according to the amount of strain, would act as a self-regulating break.

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. By Vice-Admiral MOORSOM.

The author proposed to furnish the Association with such further information on the performance of vessels at the measured mile as may induce them to appoint a Committee with the specific object of procuring experiments to be made at sea, the records of which shall be kept in such form as will enable competent persons to calculate from them the characteristics of vessels' engines and screw propellers, so that the performance of each may be duly apportioned.

To this paper are appended Forms of Returns intended to further this object.

Considering the formula $R = AW \times \frac{V^2}{2g}$ to be the foundation of all sound induction on the question of resistances, the author considers also that at present its limit of application is to the mid-section only, irrespective of hull, masts, and rigging, and to the resistance in smooth water with calm weather.

There are modifications of this equation to meet the increased resistance arising from hull, masts and rigging, wind and sea, and the form of the vessel.

But these modifications embrace only a very small range of the additional elements, because no properly-conducted experiments have been made under varied conditions *at sea*.

The resistances of sections which have come within the author's observation are comprised within the expressions—

$$R = \frac{S V^2}{3582} \text{ and } \frac{S V^2}{3219},$$

and the specific resistances due to the forms of vessels lie within 6 and 13 per cent. of R.

The following are the results of performance at the measured mile of the Duke of Sutherland's yacht, *Undine*, in July 1856, and July 1858:—

	1856.		1858.
	Ft. In.		Ft. In.
Screw diameter	6 6	....	7 10
„ pitch	11 0	....	11 3
„ length	1 4	....	1 4
Draft forward	8 3	....	8 6
„ aft	11 3	....	11 10
	Sq. ft.		Sq. ft.
Mid-section	148	....	154
Indicator Horse-power	162	....	157
	Knots.		Knots.
Speed	8·60	....	9·26
No. of revolutions	108·00	....	108·74
Slip per cent.	26·52	....	17·9

Now, the first observation that may be made is, that the larger diameter of course produced a greater thrust, and so a better result. But this does not follow.

It will be observed that the pitch is considerably less in proportion to the diameter in the new screw.

The slip was calculated beforehand, and was given to Lord Stafford, a fortnight before the trial, as about 17¾".

It will be seen that the mean average at the trials was 17·9 per cent. On the same grounds, then, that he calculated the slip of the *Undine*, the author expressed the opinion respecting the *Rattler*.

The mean of trials in Yarmouth Roads, under favourable conditions, gives a slip of 15·798 per cent. when the *Rattler's* draft of water was about 12 feet 4 inches, her section 300 square feet, and speed 8·8 knots. A trial in the Thames, in October 1851, with a mean draft of 13·9½ inches, a section of 338 square feet, and a speed of 9·141 knots, gives a slip of 17·18 per cent.

The screw duly adjusted to the form of the *Rattler* would make a slip of about 12 per cent.

The nature of the slip of the screw may be illustrated by the apparent effect upon it when the vessel is moving in a tide-way.

Out of the seven trips made by the *Undine*, at the measured mile, the two greatest extremes are selected, viz.:—

	Against Tide.		With Tide.
	Knots.		Knots.
Speed of screw	10·94	....	10·64
Do. vessel	7·32	....	10·24
Slip per cent.	33·09	....	3·76
Revolutions	98·61	....	95·89
Indicator horse-power	146·32	....	131·64

PROPOSED FORM OF TABULAR RETURN OF PARTICULARS AND PERFORMANCES OF H.M. SHIPS, *sent to the* ...
1st December 1857, *and again, 3rd May* 1858.

TABLE No. I.

Name.	Load Water-Line.					Straight of Breadth.		Mid-Section.		Displacement in Tons.
	Length.	Breadth.	Mean Draft ex. Keel.	Angles.		Vertical.	Longitudinal.	Area in square feet.	Position as to middle of length.	
				Entrance.	Run.					

TABLE No. II.

Name of Maker.	Cylinders.				Mean Pressure.		Weight per sq. inch on safety valve.	Barometer Index.	Hydrometer Index.	Nominal H. P.	Area of heating surface.		No. of boilers.	Propeller.							
	Diameter.	Length of Stroke.	No.	Revolutions per Minute.	On Piston, in lbs. per sq. inch.	In boiler, in lbs. per sq. inch.					Tubes.	Furnaces.		Diameter.	Pitch.	Length.	Angle of spiral.	Effective area of disc.	Revolutions per minute.	Resultant thrust by dynamometer.	Immersion at draft given in Table I.

TABLE No. III.

Under Steam.								Under Sail.									
Speed in statute miles per hour.				Consumption of coal in lbs. per hour.		Indicator H. P. giving the speed as before, when		Speed in statute miles per hour.		Area of sail set in sq. feet.	Angle of wind with yards.	Angle of yards with ship's course.	Angle of heeling.	Wind.		Sea.	
Trial in smooth water.		Ordinary at sea.		Trial in smooth water.	Ordinary at sea.	Trial in smooth water.	Ordinary at sea.	Trial in smooth water.	Ordinary at sea.					Direction.	Force.	Direction.	Force.
Vessel.	Propeller.	Vessel.	Propeller.														

The mean rate of the tide, therefore, was about 1·46 knot, the speed of the vessel *through the water* about 8·78 knots, and the mean slip about 18·42 per cent. From these data may be deduced the following relations, viz. :—

That the *direct* thrust of the screw *against* the tide is 6877 lbs., and the resultant 4429, and the slip, being the difference of the ratio of the square roots of these quantities, is therefore 19·75 per cent.

That the *direct* thrust *with* the tide is 6498 lbs., and the *resultant*, as before, 4429; the slip is 17·44 per cent.

The mean slip is, consequently, 18·59, which is sufficiently near the former calculation of 18·42.

A further deduction is—that the *resultant*, 4429 lbs., is at least equal to, or greater than, the specific resistance; for, if not, the slip would not have approached so close to the theoretic ratio which, as before stated, was calculated before the trial took place.

This principle of the slip may be used to correct the speed of the *Undine* in her run from Holyhead to the Mull of Cantire, when, with smooth water and light airs, she had the tide with her the greater part of the time.

The results were as under, viz.:—

Indicator horse-power	158·77
Revolutions	98·40
Speed of vessel	9·97 knots (by land).
„ screw	11·06
Slip	9·24 per cent.

Assuming the standard ratio of slip, as before determined, at about 18 per cent., the tide appears to have advanced the speed of the vessel about a mean rate of 0·87 of a knot per hour, and therefore reducing the speed through the water to 9·1 knots, or 0·16 of a knot slower than at the measured mile, the indicator horse-power being 1·68 greater.

The *Undine* was, it is believed, deeper in the water on this last occasion.

The following questions arise for solution by means of the experiments which it is my object to procure to be conducted *at sea* :—

In any given vessel, what relations obtain between the resistance due to her section in smooth water and calm weather, and the resistances the vessel herself experiences under various conditions, when under sail, under the screw, and under both?

What are the relations in any given engine of absorbed power at different speeds?

In any given screw, what are the relations between its *length* and its speed of rotation, so that a continuous disc shall be maintained? and what immersion in relation to the diameter is necessary to this result?

What are the relations between the direct thrust of any given disc and its *resultant*, and the consequent effective area and pitch and ratio of slip?

Researches of this nature, if carefully conducted, will show that the screw is capable of more accurate application, and more extended use, than has yet been made of it. Its slip is a calculable element, provided the periphery be so immersed, and the rotation such that a continuous disc is maintained.

The limits of immersion and rotation are yet to be determined.

On a proposed Floating Lighthouse. By JOSEPH JOHN MURPHY.

On a new Double-acting Steam Hammer. By WILLIAM NAYLOR, *late of Norwich, now of* 3 *New Broad Street, London, E.C.*

In considering the principle of the double-action steam hammer, we may draw some analogy with the steam gun for throwing projectiles, and assume the cylinder to be as the gun, and the piston and hammer attached as the ball. Let us assume the cylinder as one foot in length, with the top cover off, and the relative force of steam to the weight of the hammer such as by the time the piston reached the top of the cylinder, and should be moving at a velocity of 32 feet per second, it would ascend above the cylinder 16 feet, and when it had returned 16 feet by gravity it would have acquired a velocity of 32 feet per second. Let us place the cover on the cylinder, and lift up the hammer as before, only, instead of allowing it to rise up into the atmosphere until its velocity and force were counteracted by gravity, let the steam be entirely withdrawn from below the piston, and a supply introduced upon it. That which has the power of putting it in motion has also the power of stopping it, and of causing it to return with the same velocity, aided also by that which is due to its gravity; and it will be evident that, by the time it has reached the object it is intended to strike, it must have acquired more than 32 feet per second, although the space moved through is only one foot. So much for the effect of the blow. Now for time. We have assumed that, when the retarding force was employed upon the piston, it was moving with a velocity that would have carried it 16 feet, and it was returned with a still greater velocity by having the weight of the hammer with it instead of against it; so that the time must be considered as that which it would take to rise one foot at such a velocity as would, if the motive power were withdrawn, have sufficient momentum to carry or throw it 16 feet, and the time in returning could not be more than the difference in time of a body falling 16 and 17 feet. The double-acting steam hammer, working with such relative force and weight, would give the same effect as the single-acting hammer of 16 feet range; but as to time, there would be about 30 blows of the double-acting hammer to one of the single. This hammer is also capable of giving very light blows as well as very heavy ones; and it can be made either single or double acting by the circular valve, which works longitudinally in its chamber. A double hammer of 20 cwt. at work in Sheffield, has attained 200 blows per minute; and hammers of 10 cwt. have given 250 blows per minute. These hammers are under the most perfect control of the workmen, and can be worked as slow as necessary.

On a Plan for giving Alarms in Passenger Trains. *By* J. O'Neill.

This invention consists of an iron bar extending under each carriage, and suspended on a pin a little from the centre, so as to make one end heavier than the other.

The heavy end is securely held in a bridle, by a hanging latch at the end of the carriage.

The light end also passes through a bridle at the other end, and has a tongue which draws out from the bar and reaches under the latch fixed on the next carriage.

By disengaging any of the latches, the heavy end falls; and the light end, in rising, throws up the next latch, and so on to the guard's van, where it rings an alarum.

A chain or wire, fixed to the latch and brought into the carriage, gives each passenger, in the event of danger, the means of giving a signal to the guard; and a duplicate set of bars, on the other side of the carriage, enables him instantly to communicate with the driver, if necessary.

The end of each tongue has a rising point, riveted loose; so that the porter, when coupling the carriages, could put it in position for disengaging the latch, in case the carriages should become detached by the breaking of the coupling chains.

As the bars are not connected, any number of carriages can be taken off or put on at a station by merely turning the loose point on the end of the tongue up or down.

On the Gresham Buoy, for recording the Loss of Missing Ships at Sea. *By* James Oldham, C.E., *Hull.*

The object of this paper is to point out a mode by which a record of the loss of ships at sea may be attempted, where otherwise no account would ever be obtained. It is proposed that every sea-going ship, of whatever description, and particularly those carrying passengers, shall be provided with one or more copper buoys, bearing the name of the vessel and the port to which she belongs; that they shall have an Admiralty mark, and a Board of Trade number.

The "Gresham Record Buoy" (so-called from having been suggested by John Gresham, Esq., of Hull) would be provided with a chamber, and a small spring valve in the upper part, made to open outwards, and capable of resisting any ordinary pressure. Within this hollow space or chamber it is proposed to insert a slip of paper or card, or any other document, and even property, if made large enough, when all hope of safety and rescue shall fail; and at the final sinking or breaking up of the ship the buoy would float off, with the probability of being picked up at some time.

The "Record Buoy" is intended to be made of strong copper, of sufficient size to be applicable to the purpose, painted in bright-red and white stripes, and fitted with a small bell and flag on the upper part.

Three important advantages are to be derived from the use of this buoy, viz.:— 1st. The mournful satisfaction to surviving friends and relations, of being informed of what has befallen the ship and crew; 2ndly. Satisfaction to Insurance Companies and insured, that the ship and cargo are really and for ever lost; and 3rdly. The light which may be thrown on science, as such records would probably explain the cause of accidents, and the circumstances attending them,—for instance, whether owing to the build and want of strength in a ship, failure of machinery (in case of a steam vessel), or having struck on a rock, or otherwise.

On the Construction of Floating and Fixed Batteries. *By* G. RENNIE, F.R.S.

The author observed, it was now some years since the covering of the exterior of vessels of war with plates of iron was proposed by General Paixhans, of the French Artillery. This he exposed in his work, and stated that, to enable a plate to resist a 32 lb. shot, it would require a thickness of several inches, and that from the great weight of plates it was only applicable to ships of the line, and that at a cost of £24,000. On the commencement of the late Russian war, the Emperor of the French, who had paid much attention to the subject, brought it before our Government. He considered that it would very much facilitate the operations then about to take place against the Russian fortresses of Bomarsund, Helsingfors, Sweaborg, and Cronstadt. Vessels of great burden and strength were therefore constructed and covered with massive wrought-iron plates of four and five inches in thickness. The results of the few trials which were made with these iron-plated batteries were published in the journals of the day, but their success was considered to be doubtful. Many experiments of solid and hollow shot, fired from 68-lb. guns, have been made recently at Woolwich and Portsmouth, with unfavourable results. These results led the author to think that little or no success had hitherto been attained. He therefore proposed to use inclined or curved surfaces, instead of flat or point blank surfaces, as was illustrated in the models exhibited. One of these was a floating battery, or man-of-war, having its sides cased with iron plates with curved surfaces; the other a fixed or floating battery, also with curved surfaces. He claimed no other originality for this idea than in the curved forms of the plates. Mr. Rennie also exhibited various specimens of felt which had been handed to him by General Sir Charles Shaw, and several of which had been penetrated to a limited extent by rifle balls.

On a Universal Printing Press. *By* T. J. SILBERMAN.

In this paper the author describes a new method of printing by applying the pressure of a fluid to a yielding surface, laid upon an unyielding engraved surface, and this whether the surface printed be that of the vessel itself, which thus becomes the press, or whether it be communicated to another interposed yielding surface from the pliable and elastic side of the vessel, so as to print plane, curved, or angular surfaces—or whether the material to be printed be paper, felt, textile fabric, caoutchouc, leather, bladder, ceramic paste, or glass, crystal, or enamel, softened by heat; or whether it be used for the purpose of peripheric printing, as in the printing of terrestrial and celestial globes, of vessels of glass or earthenware, or as a modification of the presses in use for other kinds of printing.

The pressure, being that of a fluid communicated through a uniformly yielding surface, will be absolutely equal at every point of the surface; consequently there will be no danger of partial pressure on the plate, nor need there be a pressure upon any part of the plate beyond merely what is necessary; so that the maximum result is obtainable with the minimum of pressure. Convex or concave surfaces can be as easily printed as plane surfaces.

The author describes very fully the different methods in use for the practical application of the principle. One great advantage is its extremely simple construction, and the small space it occupies relatively to other presses; moreover, a much greater number of impressions can be taken in a given time than was possible heretofore.

As to the sort of pressure to be used; steam, or expanded or condensed air, the hydraulic press, the screw, the cam, or the eccentric or knee lever lock. If steam is used, the waste heat will warm the plates in copperplate engraving, and will thus get rid of the charcoal dust, which is so injurious to the health of the workmen.

Water, on the whole, appears to be the most desirable agent on account of its non-compressibility, and of the small quantity required in order to produce very considerable pressure; as also on account of its non-expansibility, which prevents the possibility of an explosion; for if any breakage takes place, the water simply runs out.

On a Universal Cock. *By* T. J. Silberman.

On a Wreck Intelligencer. *By* R. Smith.

It was constructed for the purpose of being thrown overboard in case of wreck or any other serious accident. Formed of copper in the shape of a ball, it consisted of two hemispherically-shaped shells, coupled together and water-tight, and intended to contain the ship's log or other information or valuables. It was painted in brilliant colours, and surmounted by a glass ball cut into facets at the top, so as to shine in the rays of the sun.

Remarks on the Bursting of Guns and Cannon. *By* S. Smith, *F.R.C.S.*

About sixty years ago, the Government sent down to Leeds 1,500 heavy Prussian muskets for the volunteers of that day: they were proved by the late Mr. Calvert, in a place near School Close. He (Mr. Smith) was then a school lad, and he and his fellow-scholars used to go and see the muskets proved, and they were sadly disappointed if some of these old arms did not burst during the trial. When they did burst, the barrels used to rise many feet, and describe many somersaults, and then he and his fellow-scholars were delighted. From this fact, the conclusion would naturally be come to, that where the gun burst at the breech, the force of the explosion would be materially diminished, and the aim of the shot altered also. His object was to prove that this theory was not correct. Fifty years ago, the gardener of Mr. Elam of Sheepscar was brought into the Leeds Infirmary to have his arm taken off, and he told this story of his accident:—He (the gardener) said he was shooting small birds in the garden, and after firing the last time, he observed he had killed two birds. He went to pick them up, and it was only on stooping down to do so that he discovered that his hand was hanging down by two or three tendons, and that the gun barrel had burst. He (Mr. Smith) made some observations about the accident. In the first place, it was singular that the man should have his arm blown off, and not know it; and secondly, it struck him as being also singular that the birds should be killed, although the gun had burst. Ten or twelve years afterwards, when he (Mr. S.) became surgeon at the infirmary, a man employed as watchman at Mr. Benyon's mill, in Meadow-lane, was brought in for treatment. The man stated that he was coming off duty about five o'clock in the morning, when he saw a crow at the top of a tree seventy yards off. He fired at it, saw it drop, and found he had killed it, but the most singular part of the business was that his gun had also burst, and evidently after the shot had left it. In 1855, a cannon was fired at Woolwich, and the ball was seen to pass from the muzzle of the gun, and to strike the butt. The gun afterwards screwed round, burst into several fragments, and injured several men in the neighbourhood. In this latter case an appreciable amount of time elapsed between the ball leaving the muzzle of the gun and the bursting of the gun at the breech. His theory consequently was, that a ball discharged from a gun was not altered in its force and aim by the bursting of the arm, but that the bursting occurred at a subsequent period to the discharge of the ball. Mr. Smith has seen many other cases proving the same fact.

On Combined Steam. By the Hon. J. Weathered.

Being convinced that ordinary steam was objectionable because it was too much saturated with water, and that surcharged steam was also objectionable for an exactly contrary reason, it being too dry, the author conceived the idea of combining the two, and discovered in practice not only that the objections to both were removed, but that in *combined steam* a new power was produced—an effective and economical combination of fire and water, applicable to all purposes for which steam is employed.

In order to apply this new system, a pipe, in addition to the usual steam pipe which conveys the ordinary steam away from the boiler, carrying with it more or less water in a liquid state, is employed to convey part of the steam from the boiler through pipes which are convoluted, or otherwise placed in any convenient form in the uptake or chimney of the boiler, and is joined to the ordinary steam pipe at or near its entrance into the cylinder. In its passage through these pipes this steam is more or less heated to a temperature of 500° or 600° Fahr. by the waste heat which is passing up the chimney: this heat, thus arrested, is conveyed to and utilized in the cylinder at temperatures varying between 300° and 400°, instead of at the low temperatures at which it is now employed.

From various experiments which have been made by the British, French, and United States Governments, all of which were attended with the most satisfactory results, which are fully detailed in the paper, the author deduces the following general inferences:—

I. That the mixed steam participates at the same time of the qualities of steam proper, and of gas, or superheated steam,—the elasticity of the one, and the increased temperature derived from the other.

II. That saturated steam contains too much vesicular water, and that superheated steam has too much the nature of gas, is a bad conductor of heat, and gives with difficulty the heat necessary to transform it into mechanical power.

III. That, in all the experiments which have been made of the mixed steam, the difference in the temperature of the steam in entering and leaving the cylinder was greater than when saturated or surcharged steam alone was used; consequently, as more heat was utilized, greater mechanical force was generated.

IV. It seems evident, therefore, that the mixture contains more *latent* caloric, which is rendered *sensible*, and consequently converted into mechanical power.

The advantages which it possesses over the use of ordinary steam are:—

1st. One-third of the wear and tear of boilers prevented, inasmuch as only two-thirds of the usual quantity of heat is required; and, as only two-thirds of the usual quantity of water is needed, one-third of the deposit in boilers is prevented.

2nd. For the same speed smaller boilers can be used.

3rd. Increased power when required in cases of emergency.

4th. Priming effectually prevented.

5th. Less danger from explosion, as the increased power is exerted in the cylinder, and not in the boiler.

6th. The system can be employed to any boiler now in use.

7th. One-third of the space now occupied by coal can be used for freight, or steamers may go one-third farther with the same coal.

8th. Fewer strokes are required.

9th. The desired pressure readily maintained at all times.

On Recent Improvements in Railway Signals. *By* C. F. Whitworth.

The recent improvements in railway signals, known as Whitworth and Gibson's combined patent, consist of the following provisions:—

1st. The improved releaser for auxiliary or distant signals, which operates to protect stations, junctions, opening bridges, and other parts where men are posted in constant charge.

2nd. Continuous signals, adapted for the protection of intermediate places between distant stations, and especially where there are tunnels or curved cuttings or inclines.

3rd. Announcing bells, which may be only mechanical or operated upon magnetically, acting either in advance or in rear of the train, so as to indicate, as may be required, the position of trains in progress.

4th. The air vessel or cushion, to regulate the motion of the signal under an excess of weight advisable to ensure the due action of the danger signal.

5th. The compensation, which acts as a perpetual adjusting screw on the wires; so that, whatever the temperature, the tension will always be equal.

6th. The engine fog signal, which is so arranged as to operate under the platform of the engine whenever a signal, at danger, is unobserved, either through carelessness or impenetrable mists.

The peculiarities of these inventions are, that the motion of the signal is totally irrespective of the velocity or impetus of the train effecting it; also that the first wheel which passes the signal-post acts on the lever completely, and so depresses the lever in contact as to prevent its rising against any subsequent wheel in the train.

The author then described by the aid of diagrams and models these various improvements, and also illustrated in addition a method of signaling by telegraph, which could be attached to the previously-described machinery, when required, when the same depression of the lever before referred to in connexion with the first signal-post brings into contact a small lever and stud, thereby completing the electric current, and acting upon an electro-magnetic bell placed in any suitable situation in advance or in rear of the moving train,—the bell ringing continuously until the second signal apparatus be reached, when the second lever breaks the current simultaneously with releasing the first signal and setting the second to danger.

On an Instrument for setting out Curve Lines. *By* R. P. Williams.

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GEOLOGY.

On some remarkable Yorkshire Fossils, including the unique Plesiosauri *in the Museum at York, with pictorial restorations by Mr. Waterhouse Hawkins.* *By* Edward Charlesworth, *F.G.S.*

On an Ichthyolite found in the Devonian Slates of East Cornwall. *By* W. Pengelly, *F.G.S.*

On the Trilobite found at the Knoll Hill, Newton Abbott. *By* W. PENGELLY, *F.G.S.*

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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.

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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 of 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'Agile de Londres, with translation;—J. S. Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

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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).

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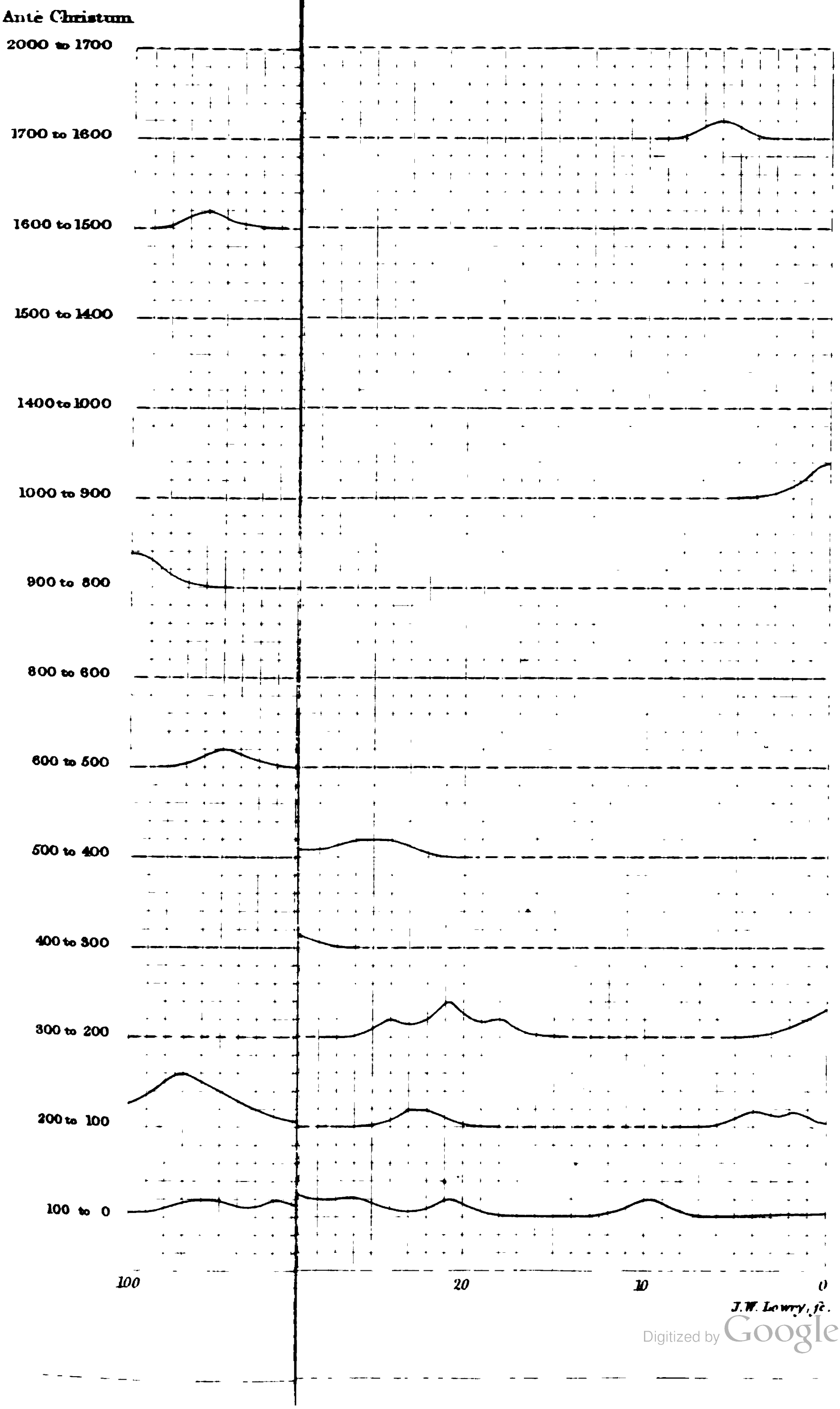

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Distribution in Time.

Curves of Monthly Seismic Energy from the entire Period.

Southern Hemisphere 223 obs.

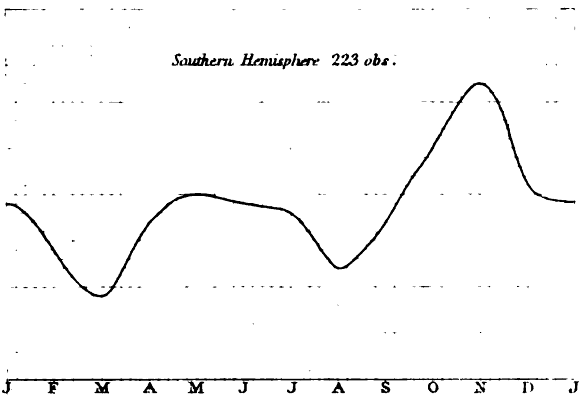

Fig. 2

Northern Hemisphere 5879 obs.

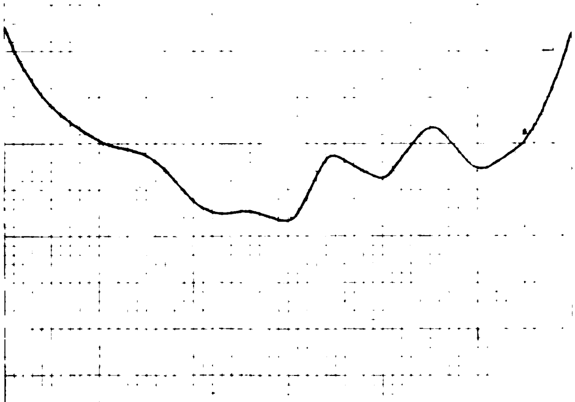

Fig. 1

Vertical Scale ⅒ that of Fig. 2.

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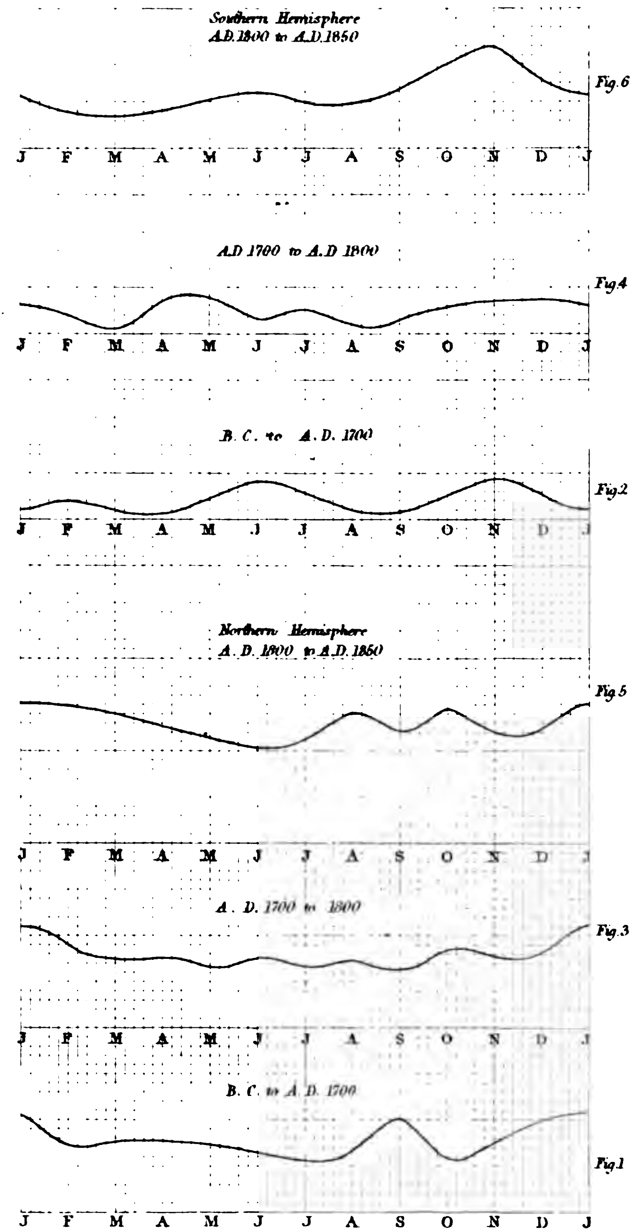
Mensual Curves of Seismic Energy

For corresponding periods. Northern & Southern Hemispheres.



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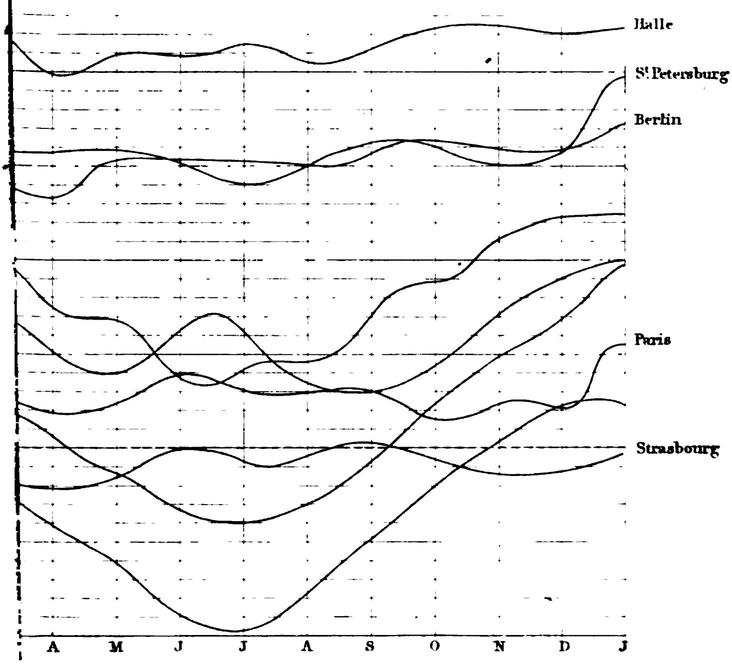
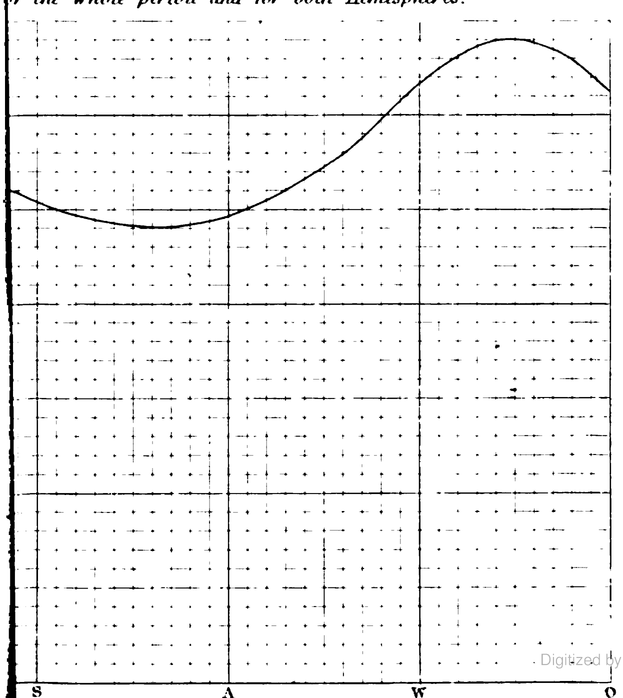
Distribution in Time.

ensual Barometric Pressure, at different latitudes



and Solstitial Curves of Comparative Seismic Energy
r the whole period and for both Hemispheres.



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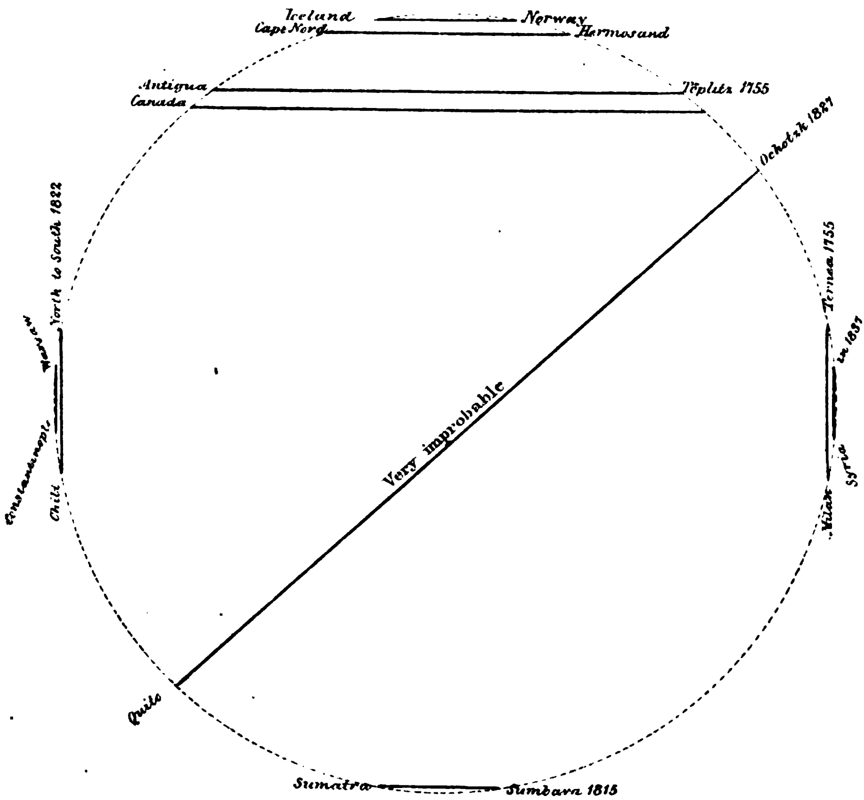
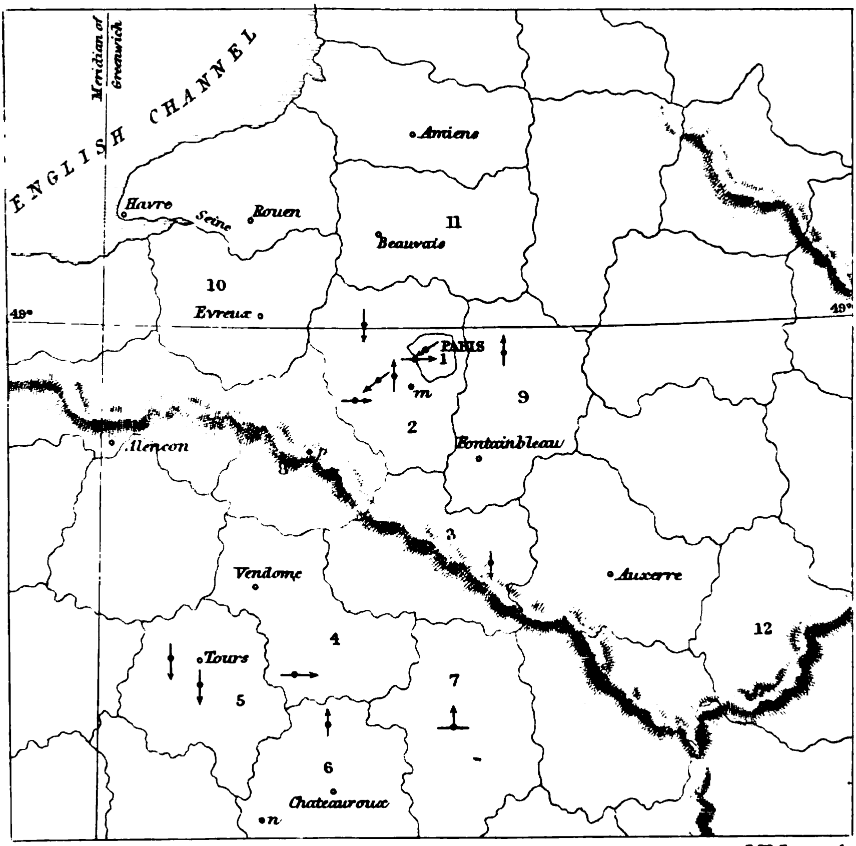
SEGMENTS APPARENTLY CUT OFF BY SOME GREAT EARTHQUAKES.



PART OF FRANCE.

DIVIDED INTO DEPARTMENTS,

Referring to the Earthquake of 5th July, 1841.



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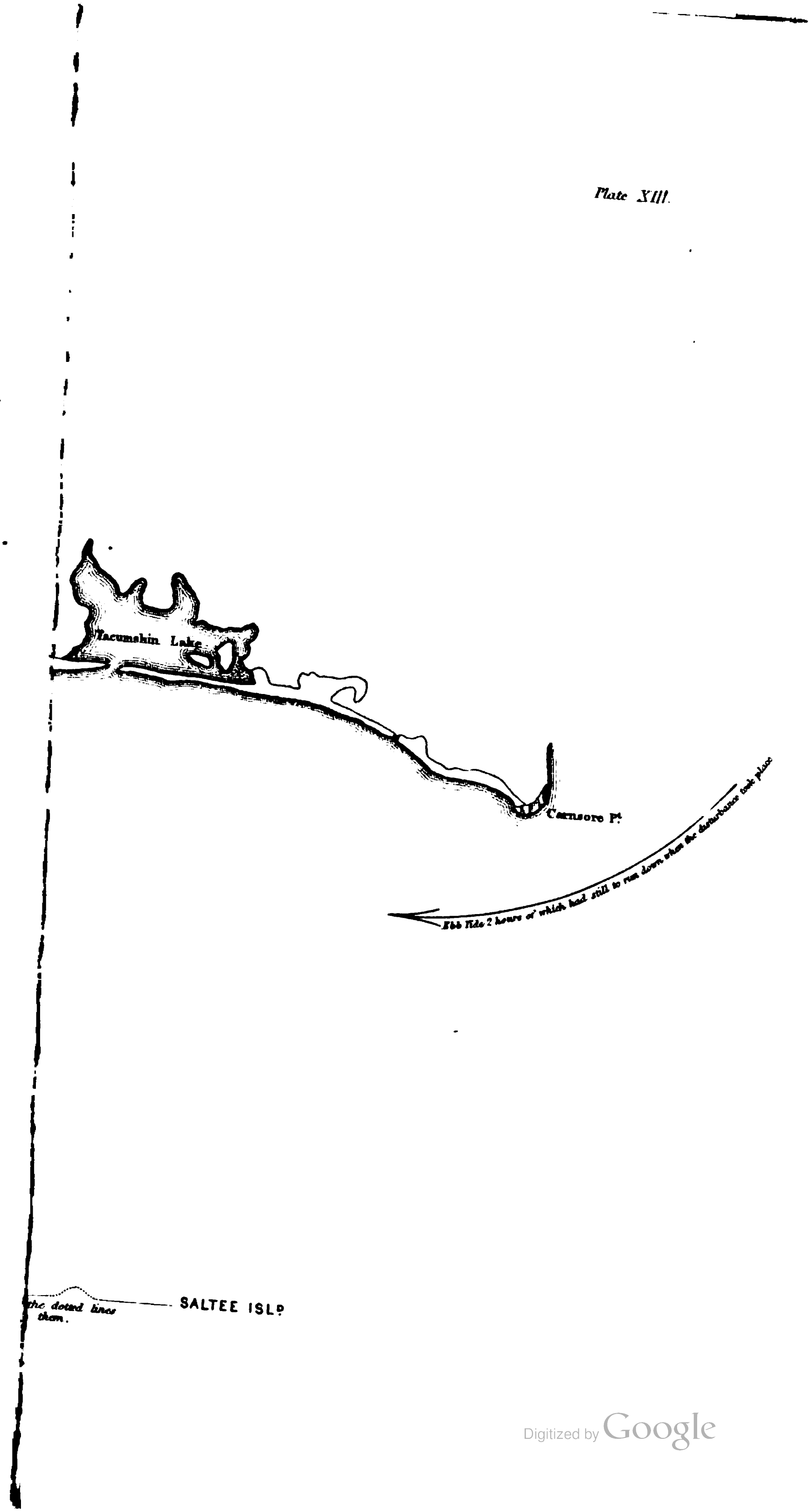
REFERENCE

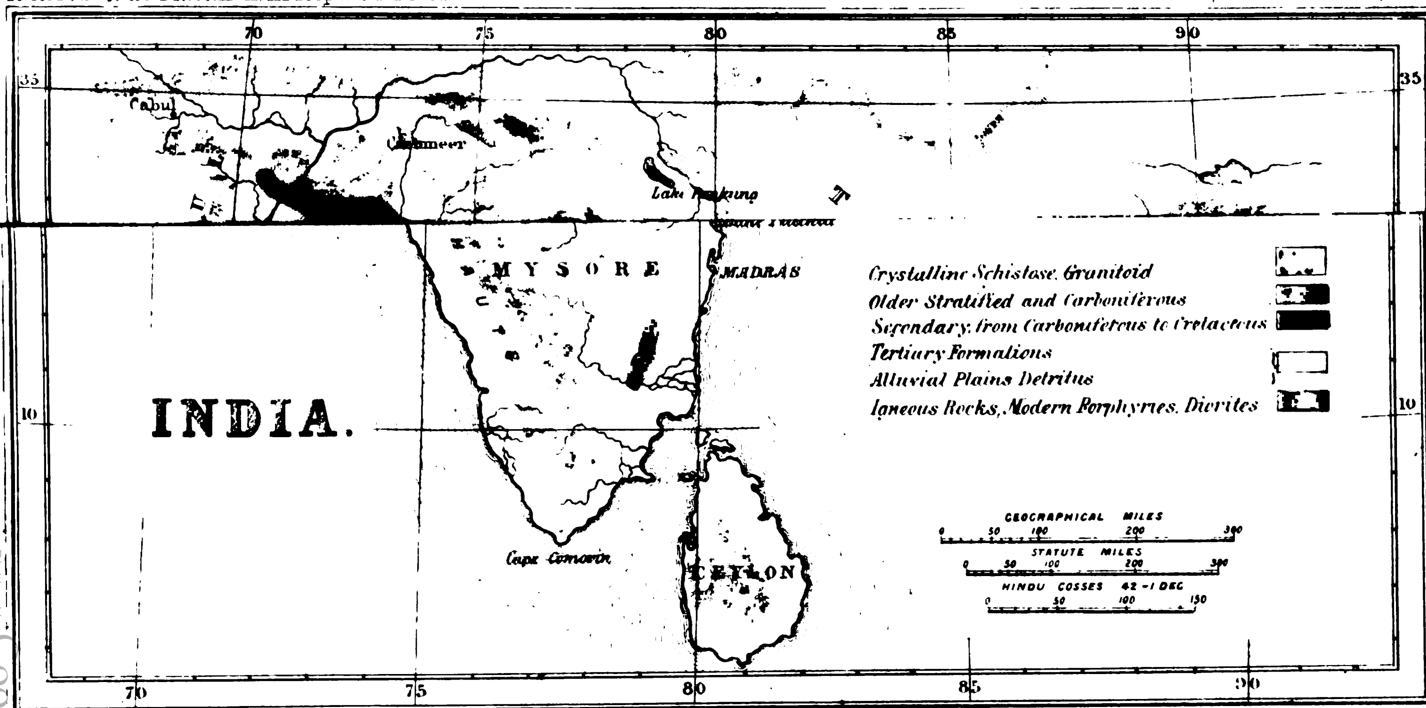
. Horizontal direction . Vertical shock.

Plate XIII.


Tacumshin Lake
Carnsore Pt
Ebb Tide 2 hours of which had still to run down when the disturbance took place
SALTEE ISLD
the dotted lines
them.

MAP OF INDIA REFERRING TO THE GENERAL AND LOCAL OBSERVED DIRECTIONS OF EARTHQUAKE SHOCKS.

Referred to as Plate XVII. in Report for 1851.



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