REPORT

OF THE

TWENTY-NINTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT ABERDEEN IN SEPTEMBER 1859.

LONDON:
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OF

THE ASSOCIATION.

OBJECTS.

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

RULES.

ADMISSION OF MEMBERS AND ASSOCIATES.

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

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

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

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

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

COMPOSITIONS, SUBSCRIPTIONS, AND PRIVILEGES.

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

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

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

The Association consists of the following classes :—

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

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

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

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

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

6. Corresponding Members nominated by the Council.

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

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

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

   Annual Members who have not intermitted their Annual Subscription.

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

   Annual Members, who have intermitted their Annual Subscription.

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

3. Members may purchase (for the purpose of completing their sets) any of the first seventeen volumes of Transactions of the Association, *and of which more than* 100 *copies remain,* at one-third of the Publication Price. Application to be made (by letter) to Messrs. Taylor & Francis, Red Lion Court, Fleet St., London.

Subscriptions shall be received by the Treasurer or Secretaries.

MEETINGS.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee at the previous Meeting; and the Arrangements for it shall be entrusted to the Officers of the Association.

GENERAL COMMITTEE.

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

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

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

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

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

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

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

SECTIONAL COMMITTEES.

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

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

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

COMMITTEE OF RECOMMENDATIONS.

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

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

LOCAL COMMITTEES.

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

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

OFFICERS.

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

COUNCIL.

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

PAPERS AND COMMUNICATIONS.

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

ACCOUNTS.

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

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

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S.L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MAKDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	Marquis of Northampton. Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount Edgecumbe.	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir D. T. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	Earl of Listowel. Viscount Adare. Sir W. R. Hamilton, Pres.R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.

SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. Professor Powell, F.R.S.	Henry Clark, M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. DelaBeche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 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., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugall, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Honourable the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. 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.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.

THE GENERAL TREASURER'S ACCOUNT from 22nd September 1858 (commencement of LEEDS MEETING) to 14th September 1859 (at ABERDEEN).

RECEIPTS.

		£	s.	d.
To Balance brought forward from last Account		238	13	3
Compositions for future Reports		10	0	0
Life Compositions at Leeds and since		467	0	0
Annual Subscriptions, ditto ditto		376	0	0
Associates' Tickets, ditto		710	0	0
Ladies' Tickets, ditto		509	0	0
12 Months' Dividends on 3 per cent. Consols		168	18	2
From Sale of Publications—	£ s. d.			
viz. For Reports of Meetings	108 15 4			
Catalogues of Stars, Dove's Lines &c.	39 10 11	148	6	3
		£2627	17	8

Examined and found correct.

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

PAYMENTS.

		£	s.	d.
By paid Expenses of Leeds Meeting, Sundry Printing, Binding, Advertising, and Incidental Payments by the General Treasurer and Local Treasurer		135	0	10
Printing Report of the Twenty-seventh Meeting	£516 14 4			
Engraving, Lithographing, &c., Twenty-eighth Meeting	257 13 7	774	7	11
Salaries, 12 months		350	0	0
Maintaining the Establishment of Kew Observatory		500	0	0
Purchase of £500 3 per cent. Consols		484	10	0
Dredging near Dublin		15	0	0
Osteology of Birds		50	0	0
Irish Tunicata		5	0	0
Manure Experiments		20	0	0
British Discoid Medusidæ		5	0	0
Dredging Committee		5	0	0
Steam-vessels' Performance		5	0	0
Marine Fauna of South and West of Ireland		10	0	0
Photographic Chemistry		10	0	0
Lanarkshire Fossils		20	0	0
Balloon Ascents		39	11	1
Balance at Bankers	£178 2 6			
Ditto due from General Treasurer and Local Treasurer	21 5 4	199	7	10
		£2627	17	8

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. (dec[d]).
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.
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Report of the Council of the British Association, presented to the General Committee at Aberdeen, September 14, 1859.

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

a. The General Committee passed the following resolutions, viz.—

"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's 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."

At a Meeting of the Council on December 17, 1858, the President stated that communications had been made on the subject of these Resolutions to the President and Council of the Royal Society, and to His Royal Highness The Prince Consort, the President Elect of the British Association for the ensuing year. He then presented the following letters, which were ordered to be entered on the Minutes:—

"Windsor Castle, December 1, 1858.

"Dear Sir,—I have been commanded by His Royal Highness The Prince Consort to acknowledge with thanks the receipt of the series of resolutions adopted by the Council of the British Association, relative to the extension of the field of Magnetical and Meteorological Observations.

"His Royal Highness would be glad to be informed whether it is expected from him, as President Elect of the Association, that he should take any steps with reference to the object the Council has in view, and if so, what they should be.

"I have also to thank you, by His Royal Highness's desire, for the copy of your Address.

"I have the honour to be, dear Sir,
"Yours very faithfully,
"C. Grey."

"Burlington House, December 9, 1858.

"Dear Sir,—In reference to the inquiry manifesting the interest which His Royal Highness The Prince Consort takes in the subject of the Resolutions of the Council of the British Association lately submitted to him, we are aware that we ought not to solicit any personal or direct action of His Royal Highness in the matter; but, having laid before him the nature and reasons of the case, and His Royal Highness being fully aware of its important scientific bearings, any expression of His Royal Highness which the joint Committees may be permitted to cite in their further communications with Her Majesty's Government or with Foreign Powers, Academies, or constituted scientific authorities would, they feel confident, possess very great influence, and be productive of the most beneficial effects.

(Signed) { "B. C. Brodie, P.R.S.
"Richard Owen, Pres. Brit. Assoc."

"*To Major-Gen. Hon. C. Grey.*"

"Osborne, 11 December, 1858.

"My dear Professor Owen,—I have to acknowledge the receipt of the Copy of Resolutions adopted at a Meeting of the British Association, with respect to the measures to be adopted for the further prosecution of your Magnetical and Meteorological Experiments, which I received before leaving Windsor; and I have now seen the letter which, in conjunction with Sir B. Brodie, you have addressed to General Grey, in answer to the inquiry respecting the above-mentioned resolutions, which he made by my direction.

"I need hardly repeat the assurance of the deep interest which I take in the subject of your inquiries, or of my sense of the importance to science of the further prosecution of the observations which have been so far conducted under the auspices of the two Societies, the interruption of which, at the very moment when there is so much reason to hope for their successful completion, would be a source of deep regret. Any assistance in my power to afford, I shall at all times be most happy to render. If, therefore, you think that in your future communications with Government, or with Foreign Powers, learned Institutions, &c., it will tend in any way to facilitate your labours, or to remove difficulties, to cite my opinion, you have my full permission to state, in the strongest manner, the conviction I entertain of the importance of being enabled to establish those new points of observation in different parts of the world, and to execute those magnetic surveys to which the Resolutions allude.

"Wishing you most heartily every success in the further development of this most interesting subject,

"I remain, yours faithfully,
(Signed) "ALBERT."

It was also stated by the President that a letter had been received from the Treasury, in reply to a communication enclosing the Resolutions above given by the President of the Royal Society and the President of the British Association, from which it appeared that the Lords Commissioners of the Treasury were desirous of postponing for a year the consideration of the subject. On this it was resolved by the Council—

That the President be requested to make a further communication to the Treasury, and to suggest reasons which may induce the Lords of the Treasury to enter on the consideration of the subject at an earlier period.

In compliance with this request, the President had an interview with Sir Charles Trevelyan at the Treasury, December 18th, and having read to him the letter from the Prince Consort, expressive of His Royal Highness's deep interest in the proposed Magnetical Observations, received from Sir Charles the expression of his belief, that, if a single station for Magnetical and Meteorological Observations were applied for, intimating Pekin as its locality, by the joint Committee of the Royal Society and British Association, My Lords would be disposed to comply with such application.

The President thereupon wrote to the President of the Royal Society, to Major-General Sabine, and Sir John Herschel, and, having received their replies, communicated to Sir Charles Trevelyan that from Major-General Sabine, of which a copy is subjoined, together with the following extract from Sir John Herschel's letter, dated Collingwood, Dec. 22nd, 1858:—"The scientific importance of a five years' series of Magnetical Observations at Pekin, without Newfoundland or the other stations (Vancouver's and Falkland Islands), would be grievously diminished, and the general scope of the project defeated."

From General Sabine.

"St. Leonards-on-Sea, January 1st, 1859.

"DEAR OWEN,—I have received your letter of the 27th ult., containing a notice of your communication with Sir Charles Trevelyan, and enclosing copies of letters from Sir John Herschel and Mr. Airy.

"There would in no case have been any question of an estimate for the present year, viz. 1859. The instruments even for a single Observatory cannot be ready before Midsummer next; and those who are to be charged with the observations will require at least some weeks for a full training, before they will be ready to proceed to their destination. Supposing, therefore, but a single Observatory to be authorized, it will come properly into the estimates for 1860, though there may be a small arrear to be included for the latter part of the preceding financial year.

"Before Mr. Welsh left Kew in November last, he gave Mr. Adie the specifications for the differential instruments (for the three elements) which it is our intention to propose as most suitable for a Colonial Observatory; and Mr. Adie undertook to have them completed and ready by Midsummer next. They are to serve either for eye-observation or for continuous photographic record, or for both, *occasional* eye-observations being desirable in any case. The space which it is proposed they should occupy, is 12 feet by 6; and their relative position, as well as that of all their parts, will be determined by their being fixed into a slate floor or basement, capable of being separated into portions for more easy conveyance to a Colony, but designed, when there, to be put together and cemented into one solid floor, which must rest on a secure foundation. The protection from the weather which the instruments will require, will be (in the Colony) a double wall either of logs or of stone, having space between the outer and inner wall, and a similarly double ceiling. When the instruments are set up in the space near the Observatory at Kew, a simple boarding will suffice in lieu of double walls and ceiling, as the equalization of temperature is of no moment when the purpose is simply to give instruction in the use of the instruments. The instruments for absolute determinations will require a small separate building, in which the absence of iron will be the only requisite, the variations of temperature not being of the same moment in their case.

"It is proposed that the description and the principal instructions for the use of these differential instruments should form an appendix to Mr. Welsh's report on the self-recording Magnetic Apparatus at Kew, which apparatus has now been in steady work for some months. Mr. Welsh's report is to be presented to the Aberdeen Meeting, and will be printed forthwith.

"Viewing the importance of *time*, I took on myself in October last the responsibility of directing Mr. Adie to proceed in the construction of these instruments. On the understanding conveyed by your letter that one Observatory at least will be sanctioned, and supposing that the instruments shall be found to answer their purpose satisfactorily, I shall be relieved from the pecuniary responsibility so undertaken; but I had at any rate very little apprehension on this account; for the improvement of standard Magnetical and Meteorological instruments has been so thoroughly recognized as a proper ground of application to the Government Grant Committee, that I should not have hesitated to ask for aid from that quarter, if needed. It was probable, moreover, that had the instruments not been required by our own Government, a ready sale might have been found for them to some projected Colonial or Foreign Establishment.

"If Mr. Adie keeps his time, the Observatory will be ready for inspection and for practice early in the next summer, when it is hoped that those who are competent to judge of the suitability of the instruments will examine them, and will offer such suggestions of improvement as may be applicable, either in the present case or in Observatories for the same purpose which may be required hereafter.

"Captain Blakiston of the Royal Artillery, to whom I had written to offer the best offices in my power towards his appointment to the charge of the Vancouver Island Observatory (supposing always that His Royal Highness the Commander-in-Chief should be favourably disposed towards the employment of an Artillery detachment as the 'personnel' of the Observatory), has replied by stating his readiness to accept the charge, and to enter at once, on his return from his present employment, on the training required for the photographic work. He is the Magnetical Observer of Mr. Palliser's Survey Expedition on the east side of the Rocky Mountains. The Expedition is ordered to return to England in the next summer; consequently at the close of the summer Capt. Blakiston will be available for this duty. I may add, in evidence of the zealous interest taken by this officer in Magnetic researches, that I have very recently received from him five months of hourly observation of the Declinometer, made in the winter of last year at Fort Carlton on the Saskatchewan, in which he has himself taken the principal part. I should propose to recommend as his Assistant, either at Vancouver Island or at Pekin, Lieut. Maunsell of the Royal Artillery, who, being an Undergraduate at Trinity College, Dublin, obtained his Commission two years since by taking a high place in the competitive examination, and is now about to obtain leave of absence to take his degree at Trinity College. My personal knowledge of this Officer is but slight, but it leads me to regard him as a person of much promise in scientific respects. He has placed his services (always presuming the approval of His Royal Highness the Commander-in-Chief) at my disposal for any part of the globe at which Magnetic Observations may be required. At remote stations, such as Vancouver Island or Pekin, a second officer is highly expedient in the event of casualties, as well as for the Survey connected with the Observatory, for which the detachment will be well provided with instruments, whether such Survey be to be prosecuted by sea or land. The Assistants at Kew, who are carrying on the work of the regular photographic Magnetic Observatory there, are fully competent, and would be quite ready to give the Officers and Non-Commissioned Officers the necessary instructions in manipulation, &c.; and I know of no reason why the 'matériel' and 'personnel' of an Observatory destined either for Vancouver Island or Pekin, should not be ready to proceed to their destination in the autumn of 1859.

"The charge which would subsequently devolve upon me, would be simply that of receiving and properly preserving the monthly returns containing duplicates of the photographic traces, and the tabulated abstracts prepared from them corresponding to every hour or every half-hour as might be deemed preferable. The arrangements which Mr. Welsh has prepared for tabulating from the traces, seem to leave nothing to be desired. There is nothing onerous in this charge, which would require only suitable presses for the arrangement of the papers, and the superintendence of a Non-Commissioned Officer acting as a Clerk under my directions. The quarterly or half-yearly applications from the Observatory for supplies of chemicals, &c., would be met through the instrumentality of the Director of the Kew Observatory, who is constantly requiring supplies of the same nature for the apparatus there. When the tabulated abstracts of the first year had been received at Woolwich complete, they might be passed through the same process of analysis for the determination of the laws of the disturbances which has been exemplified in the Observations of the Colonial Observatories. This has been worked into such a thorough system, that it would proceed with only the most general superintendence on my part, and would also, I consider, occasion no serious interruption in what would at that time be the regular and staple business of the Office, *i. e.* the reduction and coordination of the Naval Magnetic Surveys. The second and third years' abstracts might be similarly treated as they arrived; and I am inclined to think that I may, without too much presumption, look forward, please God, to the probability of my being myself able to give such a provisional report of the results as might be justified by the first three years of observation. I might also look forward, but of course with less confidence, to being able to derive the laws of the secular changes of the three elements from the absolute determinations at the expiration of the six years (if then alive and in *tolerable* health), which, from the long experience which I have had in such investigations, would be far easier to me than it could well be to any other person. But whatever might be the measure of my own competency in future years, the photographic traces of the tabulated abstracts, carefully preserved and arranged, would be transferred, at the close of the series, to some place of proper deposit, where they would be available for those who, in years to come, will carry on the magnetic investigations of which the value has now begun to be appreciated.

"The comparison of simultaneous photographic records at different Observatories will constitute a distinct work, from which, very possibly, a far more complete knowledge of the laws of the disturbances may be expected; and for this the materials would be preserved and arranged: but the execution must be looked for from other hands than mine. If, as may be expected, the establishment of self-recording apparatus at Pekin or Vancouver Island be followed by the establishment of similar instruments in other places, an interchange of photographic traces might be desirable, and could be readily effected by little more than clerk's work.

"I do not encumber this already long letter with remarks on the comparative scientific value of Vancouver Island and Pekin as Magnetic Stations; both are highly important; but this much is certain, that whatever might be the value of either, that value would be greatly enhanced—far more than doubled—by there being a simultaneous and continuous record at both Stations. It has been remarked [by Sir Charles Trevelyan] that there are 'other than scientific reasons' which would give a preference to Pekin. This remark might indeed be made in other countries; but the establishment at Pekin would be unanswerably justified by the *scientific* importance of having two Stations in nearly the same latitude on the opposite shores of the Pacific.

"By recent letters from the United States, I learn that the steps taken in this country in regard to the continuance of Magnetical investigations, have already produced a corresponding feeling in that country, and a desire that one Observatory at least, on a similar plan to that which should be adopted in this country, should be established somewhere on the Eastern Sea-bord of the United States. This would in a considerable measure fulfil the objects contemplated in the suggestion of Newfoundland as a Magnetic Station. The letters of Mr. Kingston (by which it appears that, when writing to Sir John Herschel on the 26th of June 1858, I was not thoroughly informed of the full purpose of the Canadian Legislature to maintain the Toronto Observatory in fullest efficiency) may give reason to expect that, if the instruments for a *continuous* record shall be approved, the present differential instruments at Toronto, which are only adapted for eye-observation, may be replaced by the contemplated ones, which are capable of both.

(Signed) "EDWARD SABINE."

"*Professor Owen,*
President of the British Association."

At a Meeting of the Council held this morning (September 14, 1859) at Aberdeen, the following Report was received from Sir John Herschel, Chairman of the joint Committees of the Royal Society and British Association, appointed to endeavour to procure the continuance of Magnetical researches, by which the General Committee will be fully informed of the proceedings in this matter up to the present time, and will be able to judge what further steps it may be desirable to take.

The Committee of the British Association appointed to cooperate with a Committee of the Royal Society, to endeavour to procure the continuance of the Magnetic Observations, &c., have to report progress as follows:—

Immediately on the breaking up of the meeting at Leeds, the recommendation adopted by the General Committee of the Association, to the effect [" That an early communication be made of the procedure taken on that occasion to His Royal Highness The Prince Consort, the President Elect of the British Association for the ensuing year"] was duly acted upon. The particulars of this communication, together with His Royal Highness's most gracious letter to the then President of the Association, expressive of his deep interest in the subject, and his readiness to afford every assistance in his power in facilitating the labours of that body and of the Royal Society towards the accomplishment of the object in view, have been communicated to the Council, and are recorded in the Minutes of its meeting held on Dec. 17th, 1858.

The Resolutions agreed to and the Report of the Committee were also, in pursuance of the directions of the General Committee, placed before the President and Council of the Royal Society, with a request for their further cooperation,—which, it is almost needless to state, has been most cordially received and acted on.

In further compliance with the recommendations adopted by the General Committee, a communication was made of the Resolutions on the subject, by the Presidents of the Royal Society and the British Association, to the Lords Commissioners of the Treasury, as stated in the Minutes of the meeting of Council above mentioned, the immediate result being an expression of their Lordships' wish for a postponement of the subject for the present year. But on the President of the Association, pursuant to the request of the Council, having requested an interview with Sir C. Trevelyan, and reading to him the letter from the Prince Consort above mentioned, it was intimated that an application for a single station at Pekin, for Magnetic and Meteorological Observations, emanating from the joint Committee of the Royal Society and British Association, would find their Lordships disposed to comply with it. The further correspondence to which this intimation gave rise (including a letter from General Sabine to the President of the British Association, explanatory of the circumstances which would at all events create delays in the preparations for any active steps until the summer of the present year, arising from the time requisite to prepare the necessary instruments and other considerations) stands also recorded in the form of an *addendum* to the Minutes of Council of the above-mentioned date, and need not therefore be here repeated.

Since these communications, the subject, so far as the action of the Government is concerned, remains in abeyance; and it will be for the decision of the meeting of this Association now pending, whether any and what step should be further taken to recall its attention to the subject. Meanwhile, for the present no time has been hitherto lost in the preparation of instruments, so far as would be justifiable by the prospect of the establishment of at least one Observatory. General Sabine reports, in a letter to Sir J. Herschel, dated August 29th, 1859, to the following effect:—

"My dear Sir,—I went to Kew this morning, and I had the gratification of seeing the Self-recording Magnetic instruments prepared for the first of the proposed new observatories, in the house which had been erected for their examination and for the instruction of the parties who are to use them. Everything may now be said to be ready for the reception and instruction of such parties by the Assistants of the Kew Observatory. The temporary house is detached from the Observatory, so that parties under instruction will not interfere with the regular work of the Observatory instruments. Gas is introduced into the temporary house; and on consulting Mr. Stewart, I found him of opinion that about six weeks might fully suffice for the instruction of the parties both in the self-recording and in the absolute instruments (the latter are also ready, and are used in a separate house). At the end of the six weeks, therefore, the party might be ready to embark, taking their instruments away with them; and a second set of instruments might then take their place for the instruction of a party for a second Observatory. All the arrangements contemplated in my letter* to Professor Owen of January 1st, 1859, are complete, so far as the Kew Observatory, Mr. Adie, and myself are concerned; and we are ready to receive and send away the first party to their destination, whether it might be British Columbia or Shanghai, as soon as the Government pleases."

(Signed) "EDWARD SABINE."

The interval elapsed since the last meeting of the Association has not been wanting in affording proofs of the high interest taken in the subject of these observations in other countries. Foremost in expressions of willing cooperation are the leaders of public opinion on such subjects in the United States. By a communication from Dr. Bache (Superintendent of the United States Coast Survey) to General Sabine, dated June 1, it appears that he is ready to enter *con amore* into our plans, and that he has his instruments all ready at the Joint Smithsonian and Coast Survey Magnetic Observatory at Washington, and desires only to be informed what course of action shall be here determined on, to afford his ready and powerful cooperation. And by a subsequent communication of the 12th ultimo, he further reports the readiness of President Barnard, of the University of Oxford, Mississippi, to undertake, or cause to be undertaken, a series of concerted observations, provided a formal request (of course duly authorized) from General Sabine be made to that institution to such effect, such a report being necessary to obtain the requisite appropriation of funds from the Board of Trustees.

The officers also of the American Association for the Advancement of Science have, we understand, been instructed by that body in their meeting at Springfield, to express to the officers of the British Association their interest in these magnetic proceedings.

Senhor Da Silva, successor to Senhor Pegado in the direction of the Meteorological Observatory at Lisbon, has expressed his wish to join in the system of magnetic observation to be undertaken in England, an object which he considers might be accomplished provided the British Government would interest itself with the Portuguese in favour of the undertaking, and suggesting that in that event a Portuguese officer might be instructed at Kew in the use of the instruments.

The project for the establishment of a Magnetic Observatory on the Eastern Sea-bord of the United States, and the determination of the Canadian Legislature to maintain the Toronto Observatory in full efficiency, are noticed in Colonel Sabine's letter already referred to; and in the event of a British establishment at Vancouver's Island being procured in addition to Shanghai or Pekin, would complete, in conjunction with the existing Russian Observatories, and with one which might very possibly be established by the University of Kasan in lat. 55° 45′ N., under the able direction of Professor Bolzani (who has expressed his desire to procure self-recording magnetic instruments similar to those of Kew, and to adopt the proposed system of observations), a chain of stations in considerable north latitude, which would surround the Pole, and afford a connected series of most valuable observations.

Though not in immediate connexion with the direct object of this Report, your Committee cannot refuse themselves the mention, as matters of Magnetic progress since the last meeting of the Association, of the completion of Mr.

* This is the letter above alluded to as forming part of the Minutes of Council of December 17, 1858.

Welsh's Magnetic Survey of Scotland, as having led to important conclusions as to the nature of the changes which have taken place in the magnetic system of the British Isles since 1837,—changes corroborated by a series of determinations at several stations along the South-western and Southern coasts of England, obtained by General Sabine himself in the course of the current year, since the re-establishment of his health has permitted his invaluable services to become once more available to science.

In concluding this Report, your Committee cannot but observe that all the reasons which weighed with them in recommending, jointly with the Committee appointed by the Royal Society, the Resolutions adopted by the General Committee of the British Association at their meeting of last year, for the establishment of Observatories for an additional period of five years at the stations named in their last Report, appear to them to remain in full force; and that even supposing the idea of a station on the Falkland Isles, and even Newfoundland, to be relinquished, they would continue to urge, as fitting objects for recommendation to Government, those of Vancouver's Island and Shanghai.

While nothing has occurred to weaken the general reasons adduced in that Report, they appear to have, in one respect, gained some degree of additional weight from the reappearance, during the present year, of the Solar Spots in great abundance, accompanied with exhibitions of auroral phenomena, and of an unusually hot and dry season—all in conformity with the law of periodicity alluded to in it as connecting, in some at present hidden and problematic manner, these phenomena with the magnetic disturbances.

(For the joint Committees) J. F. W. Herschel.

Postscript.—The following Memorandum, drawn up and communicated by General Sabine, containing a synoptic statement of the proceedings taken in respect of Magnetic Surveys at the instance or through the intervention of the British Association, may, in the opinion of the Committee, be very properly appended to this Report.

A Memorandum regarding Magnetic Surveys which have originated, or been promoted by the British Association for the Advancement of Science.

August 19, 1859.

1. The first occurrence, it is believed, of a survey being undertaken for the express purpose of determining the positions and values of the isomagnetic lines of declination, dip, and force corresponding to a particular epoch over the whole face of a country or state, was the Magnetic Survey of the British Islands, executed in 1834–1838 by a committee of members of the British Association, acting upon an enlarged view of a suggestion brought before the Cambridge Meeting of the Association in 1833. The results of this Survey, in the determination of the isoclinal and isodynamic lines in Great Britain and Ireland corresponding to the epoch of January 1st, 1837, were published in a memoir in the Transactions of the British Association for 1838; and in the determination of the isogonic lines, in the Philsophical Transactions for 1849, Part II.

2. At the Newcastle Meeting of the Association in 1838, a resolution was passed recommending to Her Majesty's Government the equipment of a Naval Expedition for the purpose of making a Magnetic Survey in the Southern portions of the Atlantic and Pacific Oceans, and particularly in the higher latitudes between the meridians of New Holland and Cape Horn. This recommendation, communicated to and concurred in by the Royal Society,

gave rise to the voyage of Sir James Clark Ross to the Southern and Antarctic Regions in the years 1839–1843. The magnetical results, in the determination of the isomagnetic lines over a large portion of the southern hemisphere, were published in the Phil. Trans. for 1842, Art. II.; for 1843, Art. X.; and 1844, Art. VII.: and one part yet remains to be completed, comprehending the meridians between Cape Horn and the Cape of Good Hope; its publication having been deferred in consequence of the more pressing publications of the Colonial Observatories.

3. A proposition for a Magnetic Survey of the British Possessions in North America was brought before the British Association in a Report published in their Transactions for 1837, and having been subsequently submitted to the Committee of Physics of the Royal Society, received in 1841 the recommendation of the Royal Society to Her Majesty's Government. The Survey, having been authorized by the Treasury, was carried on in connexion with the Magnetic Observatory at Toronto in Canada, under the direction of the Superintendent of the Colonial Observatories, by Lieut. (since Colonel) Lefroy, R.A. The results in regard to the isoclinal and isodynamic lines have been published in the Phil. Trans. for 1846, Art. XVII. The declination observations have been reduced and coordinated with similar observations made in the succession of Arctic Voyages between 1818 and 1855, in a memoir, now in preparation, which will include the British Possessions in North America and the countries which have been explored to the north of them.

4. The Survey of Sir James Ross in 1839–1844 having left a portion of the magnetic lines in the southern hemisphere undetermined between the meridians of 0 and 125° E., an application was made in 1844 to Her Majesty's Government by the Royal Society, to complete this remaining portion under the direction of the Superintendent of the Colonial Observatories. This was accomplished in 1845 by Lieut. (since Captain) T. E. L. Moore, R.N., and Lieut. (since Major) Henry Clerk, R.A., in a vessel hired by the Admiralty for the purpose, and despatched from the Cape of Good Hope. The results of this Survey were published in the Phil. Trans. for 1846, Art. XVIII.

5. At the Cambridge Meeting of the British Association in 1845, a recommendation was made to the Court of Directors of the East India Company, that a Magnetic Survey should be made of the Indian Seas in connexion with the Magnetic Observatory at Singapore. This recommendation was communicated to and concurred in by the Royal Society. The Survey, having been entrusted to Captain Elliot, of the Madras Engineers, was completed in 1849, and the results were published in a memoir by Captain Elliot in the Phil. Trans. for 1851, Art. XII.

6. A proposition for a Magnetic Survey of British India having been submitted to the British Association, in a Report printed in the Transactions for 1837, a scheme for the execution of such a Survey was submitted to the Court of Directors of the East India Company by Captain Elliot on his completion of the Survey of the Indian Seas; and having been referred to the Royal Society, received their warm approbation. The Court of Directors having approved the scheme suggested by Captain Elliot, that officer proceeded to India in 1852 for the purpose of carrying it into execution, but died shortly after his arrival at Madras, in August 1852, having but just commenced the operations of the Survey.

7. In April 1853 a letter was addressed to the President of the Royal Society by the Prussian Minister, Chevalier Bunsen, recommending, by desire of His Majesty the King of Prussia, the Messrs. Schlagintweit, well known by their physical researches in the Eastern and Western Alps, as fitting suc-

cessors to Captain Elliot in the Magnetic Survey of India. In transmitting Chevalier Bunsen's letter to the Court of Directors, the Royal Society took occasion to express their strong opinion of the importance of completing this Survey, and their belief of the competency of the Messrs. Schlagintweit for such employment. These gentlemen, having been appointed accordingly by the Court of Directors, and supplied with the necessary instruments, in the use of which they were specially instructed at the Kew Observatory, sailed for India in 1855, and continued their observations through the years 1856, 1857, and 1858, during which they determined the magnetic elements at 69 stations in British India, including some stations north of the Himalayan chain. These observations have been prepared for publication by the Messrs. Schlagintweit, and the printing of the volume containing them is nearly completed.

8. Twenty years having elapsed since the former Survey of the British Islands (referred to in the first paragraph) was made, the British Association deemed that a sufficient interval had passed to make a repetition of the survey desirable, with a view to the investigation of the effects of the secular change which the magnetic lines are known to undergo. Accordingly, at the Cheltenham Meeting of the Association in 1857, the same gentlemen who had made the Survey of 1837, and who, as it happened, were all living, were requested to undertake a fresh Survey. This has been for the most part accomplished, and the observations in England, Scotland, and Ireland are now undergoing the process of reduction and coordination; and it is hoped that a part, if not the whole, will be completed in time to be included in the volume of the Transactions of the Association in 1859.

EDWARD SABINE.

b. The General Committee at Leeds having directed 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,—

The President was requested to communicate thereupon with the Marquis d'Azeglio, the Sardinian Minister, and the Council have now the pleasure of communicating the following statement from Professor Owen as the result of that communication:—

"I wrote to his Excellency, the Marquis d'Azeglio, on the 3rd February; and on the 4th received an acknowledgement of my letter, with the assurance that the subject of it would be forwarded to the competent authorities at Turin, accompanied by a special recommendation from his Excellency.

"On the 17th February, I was favoured by a letter from the Marquis d'Azeglio informing me that the Minister of the Interior had been occupied by the preparation of new regulations on the subject of the Guides at Chamouni; and that, in all probability, the new regulations, based upon a principle of wider liberty of action, would be rigorously enforced at the commencement of the summer of 1859; and that he had every reason to believe it would satisfy all the requirements of scientific travellers in the Piedmontese Alps.

"I communicated this favourable reply to Professor Tyndall, and received the expression of his entire satisfaction in the result of the intervention of the British Association."

2. The Council has been informed by a letter from Dr. A. D. Bache to the General Secretary, that at the Meeting of the American Association for the Advancement of Science, held at Springfield in August 1859, the officers were instructed to express to the British Association for the Advance-

ment of Science, the warm interest which is taken in the United States of America in the success of the measures proposed for the continuation of Magnetic Observatories. Subjoined is the official communication which has since been received :—

" *To His Royal Highness* THE PRINCE CONSORT, *President, and to the other Officers of the British Association for the Promotion of Science.*

"In accordance with the request of the American Association for the Advancement of Science, its officers beg leave to communicate the following resolutions :—

Resolved,—That the American Association for the Advancement of Science regards with great interest the efforts making by the British Association for the Advancement of Science, to induce the re-establishment of the Colonial Magnetic Observatories, for a new series of simultaneous Magnetic and Meteorological observations.

Resolved,—That the Officers of the Association be requested to communicate this resolution to the Officers of the British Association.

" STEPHEN ALEXANDER, *President.*
" EDWARD HITCHCOCK, *Vice-President.*
" W. CHAUVENET, *General Secretary.*
" JOSEPH LOVERING, *Permanent Secretary.*"

" Springfield, Mass., August 10, 1859."

5. The Council has been informed that a deputation has been appointed, and will attend at Aberdeen, to invite the British Association to hold its meeting for 1860 at Oxford, and that invitations will also be presented, for 1861 and following years, from Manchester, Cambridge, and Newcastle-upon-Tyne.

6. The following Report was received from the Kew Committee, and was ordered to be entered on the Minutes.

Report of the Kew Committee of the British Association for the Advancement of Science for 1858-1859.

It is with deep regret that the Committee have to report the decease of the late Superintendent of the Observatory, Mr. John Welsh, who died at Falmouth on the 12th of May, where he had removed for a short time for the recovery of his health.

Mr. Welsh's position as a man of science was too well known to require any reference from the Committee, yet they may be permitted to refer to those aspects of it which have come more prominently under their view during the long and pleasant intercourse which has so unhappily come to an untimely termination.

Mr. Welsh entered the Observatory on the 27th of August, 1850, as an assistant to Francis Ronalds, Esq., F.R.S., who for some years had superintended the management as the Honorary Director. Mr. Ronalds retired in 1852 to reside on the Continent, since which time, with the exception of a short interval, Mr. Welsh has been the Superintendent; and the present efficiency and recognized scientific standing of the Observatory may be assumed to be in a great measure due to the zeal and remarkable ability with which he discharged his duties: ingenious in devising new arrangements, laborious and persevering in their execution, he was eminently qualified to direct and superintend the arrangements of a practical physical observatory.

His knowledge of science in general, but more particularly of Meteorology and Magnetism, was extensive and accurate; in all branches of these sciences he was an eminent authority, having clear and comprehensive views, possessing also a sagacious insight into remoter possibilities.

His zeal for science was signally displayed in the four balloon ascents which he undertook in 1852 with some personal risk, and from which he obtained valuable results (Phil. Trans. vol. cxliii. part 3).

Possessed of an amiable disposition, of singular warmth of heart and sincerity of character, his loss as a friend is mourned by all the members of the Committee and by many members of the Association.

The published annual Reports of the British Association, and the Transactions and Proceedings of the Royal Society, contain many valuable contributions of Mr. Welsh, and these alone would entitle him to be placed in the ranks of those to whom the Science of this country must ever be deeply indebted.

Several gentlemen offered themselves as candidates to succeed Mr. Welsh; the Committee, in selecting Mr. Balfour Stewart, who was formerly his Assistant in the Observatory, believe they have appointed a gentleman who is not only competent to fulfil the duty of Superintendent, but who, from the experience he obtained under the direction of Mr. Welsh, is peculiarly fitted for the office.

Mr. Stewart entered on his duties on the 1st of July last. He reports that he found all the Assistants discharging their respective duties. Mr. Chambers was assiduously attending to the Magnetical, and Mr. Beckley to the Mechanical Department of the Observatory. Mr. Magrath had charge of the Meteorological verifications, and Mr. Whipple he found of much use in the general work of the Observatory.

During the past year, in the Magnetical Department, Constants have been determined for a Unifilar Magnetometer belonging to Dr. Pegado, of Lisbon, and also the temperature correction and induction coefficient for its accompanying magnet.

A Dip Circle belonging to Padre Secchi, For. Mem. R.S., and Astronomer at Rome, as also one belonging to Prof. Hansteen, have been compared with the Kew instrument, adjustments made for the determination of total force by Dr. Lloyd's method, and observations made at the Observatory as a base station.

Temperature corrections and induction coefficients have been obtained for magnets R_2 and R_6 belonging to General Sabine.

Dr. Bergsma, of Utrecht, has received instructions in the use of Magnetical Instruments at the Observatory.

An extensive series of dip observations, and also periodical determinations of Magnetic force and declination, have been made: and a Manual of Instructions, for the use of the Instruments adopted for those purposes at the Kew Observatory, has been drawn up and printed at the expense of the Admiralty, by whom 250 copies have been presented to the Observatory.

The Committee think it right to mention, that the magnetical work, the details of which have now been given, was executed in the absence of Mr. Welsh by Mr. Chambers, in a manner very creditable to his intelligence and industry, and satisfactory to the Committee.

The Self-recording Magnetometers have continued in constant operation; their instrumental coefficients were determined by Mr. Welsh. The death of this gentleman prevented his completing the Report called for at the last

Meeting of the Association on the Self-recording Magnetical apparatus at the Observatory; but the Report is in progress of completion by Mr. Stewart, and will be printed in the next volume of the Transactions of the Association.

An instrument has been devised at the Observatory for tabulating the values of the magnetic elements from the curves given by the Magnetographs. As the staff of Assistants at the Observatory is not sufficiently large to undertake these tabulations, General Sabine has undertaken to have the results tabulated at Woolwich for every hour; but the instrument is capable of furnishing data for much smaller intervals, and may under special circumstances be thus used.

The observations connected with the Magnetic Survey made in Scotland by Mr. Welsh, are in progress of reduction by Mr. Stewart, and the result will be presented as a report to the present meeting.

Self-recording Magnetic Instruments designed for the first of the Colonial Observatories which have been proposed to Her Majesty's Government have been completed by Mr. Adie, from drawings prepared by Mr. Beckley from the design of the late Mr. Welsh, and are set up in a wooden house erected near the Observatory, for the purpose of affording an opportunity to the proposed Magnetical observers to be instructed in the use of the Self-recording Instruments.

Since the last meeting of the Association the unfortunate death of Mr. Welsh has retarded the experiments with the Photoheliograph, but from time to time they have been gone on with, at first by Mr. Chambers, who obtained some very fair results, and latterly by Mr. Beckley, as his other duties have permitted; and in order that they might be prosecuted more continuously, the Committee have fitted up a Photographic room in close contiguity to the instrument. This addition to the photographic establishment has been attended with the most promising results; and the Committee have satisfaction in reporting that the difficulties which have hitherto presented themselves in the way of a daily photographic record of the sun, appear to be almost entirely surmounted. Since the erection of the photographic room, Mr. Beckley has been enabled to make a series of experiments, and has turned his attention to the exact determination of the chemical focus of the Photoheliograph, which there was reason to suspect did not correspond precisely with the visual focus; for although the chromatic aberrations of the object-glass had been specially corrected in order to obtain that result, the secondary glass, which magnified the image, was not so corrected. It has been found, after repeated trials, that the best photographic definition is obtained when the sensitized plate is situated from $\frac{1}{10}$th to $\frac{1}{8}$th of an inch beyond the visual focus in the case of a 4-inch picture; and that when this adjustment is made, beautiful pictures are obtained of the sun 4 inches in diameter, which still bear magnifying with a lens of low power, and show considerable detail on the sun's surfaces besides the spots, which are well defined.

Mr. De la Rue, by combining two pictures obtained by the Photoheliograph at an interval of three days, has produced a stereoscopic image of our luminary which presents to the mind the idea of sphericity.

Under Mr. De la Rue's direction, Mr. Beckley is making special experiments having for their object the determination of the kind of sensitive surface best suited for obtaining perfect pictures; for it has been found that the plates are more liable to stains of the various kinds, known to photographers, under the circumstance of exposure to intense sun-light, than they would be if employed in taking ordinary pictures in the camera.

Now that the photographic apparatus has been brought to a workable state, Mr. De la Rue and Mr. Carrington, joint Secretaries of the Astronomical Society, propose to devote their attention to the best means of registering and reducing the results obtained by the instrument, provided the funds which may be necessary are placed at their disposal.

The difficulties which have stood in the way of bringing the Photoheliograph into an efficient state of work, were such as required no ordinary degree of perseverance to surmount; and the Committee have therefore the greater satisfaction in reporting that these have been overcome, in so far as to render the Photoheliograph a valuable recording instrument:—the minor improvements still contemplated have for their object the production of pictures as free as possible from the spots and blemishes to which all photographs are liable, and sun pictures in particular.

It was mentioned in the last Report that Mr. Beckley had suggested certain modifications of his anemometer. He was requested to prepare a description of this instrument, which description was published in the last volume (page 306) of the Reports of the Association.

The verifications of Meteorological Instruments have been continued on the usual plan.

The following have been verified from the 1st of July 1858 to the 1st of August 1859:—

	Barometers.	Thermometers.	Hydrometers.
For the Admiralty	78	120	
For the Board of Trade	76	474	80
For Opticians and others	33	317	12
Total	187	911	92

An application having been made by Colonel Sykes for the instruments used by Mr. Welsh in his Balloon ascents, these were got ready and their corrections determined. The instruments, consisting of one barometer, two Regnault's hygrometers with attached thermometers, eleven separate thermometers, three vacuum tubes obtained from Dr. Miller, and a polarimeter, with their respective fittings, were delivered to Colonel Sykes, and are now in charge of the Balloon Committee.

On the 21st of May, 1859, the Chairman of this Committee addressed a letter to the Secretary of the Admiralty, stating that by the direction of the Committee he had been desired to acquaint the Lords of the Admiralty that the Austrian frigate 'Novara,' which left Europe on a voyage of circumnavigation and scientific research, was furnished with scientific instruments from the Kew Observatory, that her officers received instruction for their use from Mr. Welsh and his assistants, and that several communications had been received from the 'Novara.' This vessel has since arrived.

The following correspondence has taken place between Senhor da Silva of Lisbon and General Sabine.

"Lisbon, July 11th, 1859.

"Sir,—Having succeeded Dr. Pegado in the direction of the Meteorological Observatory at Lisbon, I shall be very happy if I can assist in, or promote the important operations connected with magnetism that England is about to undertake.

"But previous to promising you on my part, I am desirous of knowing—

"1st. If it will be possible to instruct a Portuguese official at Kew.

"2nd. If the English Government would be disposed to interest that of Portugal in this scientific expedition.

"3rd. To whom we ought to apply in order to complete our collection of

Magnetic Instruments, having already an Inclinometer of Barrow, a Declinometer of Jones, and a Unifilar of the same maker.

"Finally, to solicit you to aid us with your excellent counsel, of which we are in want.

"You will please pardon my having taken this liberty of addressing you, but wishing to serve science to the utmost of my power, I trust that you will favour me with your aid.

"Accept the assurance of my high consideration and respect.

"I have the honour to be, Sir,

"Your obedient Servant,

(Signed) "J. A. DA SILVA."

"*Major-General Sabine, Woolwich.*"

"13 Ashley Place, London, S.W.

"SIR,—I beg to acknowledge the receipt of your letter. I am authorized by the Committee of the Directors of the Kew Observatory to say, that it will give them great pleasure to afford every facility for instruction and practice, both in the self-recording magnetic instruments and also in those designed for absolute determinations, to an officer who may be sent by you for that purpose; and should you desire to have any instruments made in England similar to those in use at Kew, the Committee will be most happy to superintend their construction, verify them, and send them out. In regard to an application from our Government to yours, I am unable at present to say anything, inasmuch as the decision upon the establishment of our own proposed observatories will not be taken until the autumn: the restoration of peace is a favourable event.

"I beg you, Sir, to be assured that it will at all times give me great pleasure to be of any use to your Observatory in my power.

"I have the honour to be, Sir,

"Your obedient Servant,

(Signed) "EDWARD SABINE."

"*Senhor J. A. da Silva,*
Observatorio Meteorologico, Lisbon."

The following Resolution was passed by the General Committee at the last Meeting of the Association at Leeds:—

"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."

The Committee are strongly impressed with the importance of the preceding recommendation, and would have great satisfaction in giving their best attention to the subject, but the works they have in hand are already beyond the pecuniary means placed at their disposal, and the Committee are unwilling to impair the credit which the Kew Observatory is obtaining by undertaking more than the income enables them to accomplish effectively.

The Committee finding that in future they will not require more than one half of the land attached to the Observatory, for which an annual rent of £21 is paid, notice to that effect has been given to Mr. Fuller.

In the last Annual Report to the Council at Leeds, the Committee suggested "that the time had arrived when strenuous exertions should be made to obtain such an amount of pecuniary aid as would ensure the efficient working of a practical physical observatory;" and they also stated "that the probable future expenditure could not be fairly estimated under £800 per annum." At that time the Committee contemplated the engagement of a photographic assistant, and also some other arrangements which they were compelled to forego, as it will be seen, by the financial statement annexed to this Report, that the expenditure of the past year exceeded the income by the sum of £106 2*s.* 1*d.*, the amount of the former being £675 14*s.* 8*d.*, while the total income was only £569 12*s.* 7*d.*, £69 12*s.* 7*d.* having been received for the verification of instruments: this source of income is year by year decreasing, as explained in a former Report, in consequence of the Government departments being now nearly supplied with standard meteorological instruments.

The Committee, in presenting this Report, have to repeat their former suggestions, that means should be taken to obtain effectual pecuniary aid for the support of an establishment which has for so many years laboriously and effectually carried out those scientific objects for which it was founded, more particularly since the appointment of a salaried superintendent, assisted by a competent staff, whose individual services have always been obtained at the most moderate scale of remuneration.

Kew Observatory, Aug. 29, 1859. JOHN P. GASSIOT, *Chairman.*

Accounts of the Kew Committee of the British Association from September 22, 1858 *to September* 14, 1859.

RECEIPTS.	£	s.	d.	£	s.	d.
Balance from last account				114	11	9
Received from the General Treasurer				500	0	0
„ for the verification of Instruments—						
from the Board of Trade	46	3	0			
from Opticians	23	9	7			
				69	12	7
				£684	4	4

PAYMENTS.	£	s.	d.	£	s.	d.
Salaries, &c. :—						
To late Superintendent, three qrs. salary	150	0	0			
B. Stewart, one quarter ending Oct. 1, 1859	50	0	0			
C. Chambers, one year, ending Oct. 6	100	0	0			
J. V. Magrath, one year, ending Aug. 14	70	0	0			
R. Beckley, 51 weeks, ending Sept. 12, at 35*s.*	89	5	0			
G. Whipple, 15 weeks, ending Jan. 3, at 10*s.*	7	10	0			
Ditto, 36 weeks, ending Sept. 12, at 12*s.*	21	12	0			
				488	7	0
Apparatus, Materials, Tools, &c.				37	9	4
Ironmonger, Carpenter, and Mason				17	12	2
Printing, Stationery, Books, and Postage				5	7	1
Coals and Gas				54	0	0
House Expenses, Chandlery, &c.				19	11	11
Porterage and petty expenses				8	2	2
Rent of Land				10	10	0
Furnishing Assistants' Rooms				34	15	0
Balance in hand				8	9	8
				£684	4	4

I have examined the account and compared it with the vouchers presented to me, and find that the Balance in hand is Eight Pounds Nine Shillings and Eightpence.

2nd Sept., 1859.

R. HUTTON.

7. The Report of the Parliamentary Committee of the British Association to the General Committee has been received by the Council, and is herewith transmitted.

Report of the Parliamentary Committee to the Meeting of the British Association at Aberdeen, in September 1859.

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

We have taken the opinion of Counsel on the question, whether it is expedient to cause a Bill to be prepared to facilitate the appointment of new Trustees to Museums and other Scientific Institutions.

The Opinion is appended to this Report.

A vacancy has occurred in that division of our members who represent the House of Commons, by the retirement of Mr. Edward J. Cooper, of Markree, from Parliament.

We cannot but deeply regret the loss of the services of a gentleman who has devoted a great part of his life to the successful promotion of Astronomical Science. It will also be for the General Committee to determine whether they will appoint another member of the House of Commons in the place of the Earl of Ripon, who, since his election at Leeds, has taken his seat in the House of Lords. This case is not in terms provided for in the original constitution of our Committee; but we are of opinion that it was intended that no one should cease to belong to our body, as long as he continued a member of either House of Parliament.

While, however, there can be little doubt that Lord Ripon continues a member of the Parliamentary Committee, it may still be deemed expedient that the representatives of the House of Commons should not be diminished in number; in which case there will be two vacancies to supply. We recommend that Lords Enniskillen, Harrowby, and Stanley, and Mr. Stephenson, who have not attended during the past two years, be re-elected.

During the course of last year, an intention was manifested on the part of the Government, of greatly restricting the free distribution of scientific works published at the expense of the public, and of causing the works so undistributed to be sold at the cost price of printing and paper.

It is unnecessary to enlarge on the very injurious moral results which would accrue to Science, and the insignificant pecuniary gain to the public likely to arise from the change in contemplation; for we have reason to believe that the Government have been induced, by the representations which have been addressed to them, to abandon their original intention.

WROTTESLEY, *Chairman.*

24th August, 1859.

THE OPINION.

The 13 and 14 Vict. c. 28, is loosely drawn, and I think many cases might arise in which it would be found that its provisions are inadequate; but, as I understand that there is no intention of altering this Act, it is unnecessary to comment on it; and I pass to the consideration of whether it is practicable to extend the principle of it to personal estate, other than leaseholds, which are included in the existing Act.

I confess I do not see how such an enactment as is proposed would work, except by adding to it such conditions as would prevent its being of any practical convenience. The property under contemplation is, of course, stock in the funds and in public companies, debts, and other choses in action:—personal chattels, passing by delivery of possession, there is no difficulty about. Let us take the case of Stock in the Funds. A. B. and C. D., trustees of a Society, have £1000 Consols standing in their names. By a resolution of the Society they are removed from the trusteeship, and E. F. and G. H. are appointed. It is proposed to enact that, thereupon, the Stock shall vest in E. F. and G. H.; but, how is the Bank, which knows nothing about trusts, to be induced to pay the dividends to them? There must be something equivalent to a transfer of the Stock into their names, by direction of the old trustees, or of the Court of Chancery; and I do not see that any plan can be devised more simple and inexpensive than the present mode of transfer.

The Bank of England would certainly oppose any attempt to make them enter on their books that Stock is subject to any trust; and yet, unless it appeared on the books that the Stock is held in trust for a Society, it would not be possible to make any provision for a transfer of the Stock on production of resolutions of the Society.

It occurred to me, that Powers of Attorney, for transfer of Stock vested in trustees for Societies, might be exempted from Stamp Duty; but, on consideration, I do not see how the Bank could know what powers were lawfully exempted, without taking notice of the trusts.

The same objections would not apply to all other descriptions of personal property; but, I presume, if the proposed alteration of the law is not applicable to *Stock*, it would not be thought worth while to make it with reference to other species of property.

In the Literary Institutions Act, there is already a section (the 20th) as to the vesting of personal property; but it does not very clearly appear how it would work in such cases as are above referred to.

M. J. B.

15th January, 1859.

The following letter has been received from Baron Bentinck, in relation to the assistance given to Dr. Bergsma at Kew Observatory:—

"Netherlands Legation,
London, 10th September, 1859.

"Baron Bentinck, Minister of the Netherlands, presents his compliments to Major-General Edward Sabine, Vice-President of the Royal Society at London, and has the honour to inform him that he has been requested by his Government to express to Major-General E. Sabine the thanks of the Netherlands Government for the kind assistance which he has granted to Dr. P. A. Bergsma, when in London with a Government Mission; and also to convey to Major-General Sabine the hopes entertained by his Government that he will in future time continue to aid Dr. Bergsma with his good advices. Baron Bentinck avails himself of this opportunity to offer to Major-General Sabine the assurances of his highest consideration.

"BENTINCK."

"*Major-General E. Sabine,*
Vice-President of the Royal Society,
London."

Recommendations adopted by the General Committee at the Aberdeen Meeting in September 1859.

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

Involving Grants of Money.

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

That Professor Sullivan (of Dublin) be requested to continue his researches on the Solubility of Salts at Temperatures above 100° Cent., and on the mutual Reaction of Salts at such temperatures; and that the sum of £30, which was voted last year, still remain at his disposal for the purpose.

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

That Mr. Alphonse Gages be requested to continue his Mechanico-Chemical Experiments on Rocks; and that the sum of £25 be placed at his disposal for the purpose.

That a Committee, consisting of Dr. R. Angus Smith, Dr. Daubeny, Dr. Lyon Playfair, Rev. W. Vernon Harcourt, Professor Williamson, and Mr. Warren De la Rue, be requested to confer with the Parliamentary Committee with reference to the best mode of taking Scientific Evidence in Courts of Law; and that the sum of £10 be placed at their disposal for the purpose of meeting the expenses incident to the working of the Committee.

That Mr. Robert Mallet be requested to continue his Experiments on Earthquake Phenomena; and that the sum of £25, unexpended last year, be placed at his disposal for the purpose.

That a Committee, consisting of the Rev. Dr. Anderson, Professor Ramsay, Professor Nicol, and Mr. Page, be requested to continue the Explorations already begun by Dr. Anderson in the Yellow Sandstones of Dura Den; and that the sum of £20 be placed at their disposal for the purpose.

That a Committee, consisting of Sir Roderick I. Murchison, Mr. Page, and Professor Ramsay, be requested to direct Mr. R. Slimon in his further Exploration of the Upper Silurian Strata of Lesmahagow; and that the sum of £15 be placed at their disposal for the purpose.

That a Committee, consisting of Mr. MacAndrew (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. Worthey (Bristol), Mr. S. P. Woodward (London), Professor Allman (London), and Professor Huxley (London), be requested to conduct general Dredging Investigations, and printing of Dredging Papers; and that the sum of £50 be placed at their disposal for the purpose.

That a Committee, consisting of Dr. Ogilvie, Dr. Dickie, Dr. Dyce, Professor Nicol, and Mr. C. W. Peach, be requested to conduct Dredging Investigations on the North and East Coasts of Scotland; and that the sum of £25 be placed at their disposal for the purpose.

That a Committee, consisting of Professor Kinahan, Dr. Carte, Dr. E. Percival Wright, and Professor J. Reay Greene, be requested to conduct Investigations in Dredging Dublin Bay, and to report to the next Meeting of the Association; and that the sum of £15 be placed at their disposal for the purpose.

That a Committee, consisting of Dr. Daubeny and Dr. Lankester, be requested to cooperate with Professor Buckman in his Researches on the Growth of Plants, and to report to the next Meeting of the Association; and that the sum of £10 be placed at their disposal for the purpose.

That Professor Allman be requested to continue his Researches on the Reproductive System of the Hydroid Zoophytes; and that the sum of £10 be placed at his disposal for the purpose.

That a Committee, consisting of Dr. George Wilson, Sir John Herschel, Sir David Brewster, Professor Clerk Maxwell, Professor W. Thomson, and Mr. W. Pole, be requested to inquire into the Statistics of Colour-Blindness; and that the sum of £10 be placed at their disposal for the purpose.

That the following Members be requested to act as a Committee to continue the inquiry into the performance of Steam-vessels, to embody the facts in the form now reported to the Association, and to report proceedings to the next Meeting; that the attention of the Committee be also directed to the obtaining information respecting the performance of vessels under Sail, with a view to comparing the results of the two powers of Wind and Steam, in order to their most effective and economical combination; that £150 be placed at their disposal for this purpose:—Vice-Admiral Moorsom; The Marquis of Stafford, M.P.; The Earl of Caithness; Lord Dufferin; Mr. William Fairbairn, F.R.S.; Mr. J. Scott Russell, F.R.S.; Admiral Paris, C.B.; The Hon. Capt. Egerton, R.N.; Mr. W. Smith, C.E.; Mr. J. E. McConnell, C.E.; Mr. Charles Atherton, C.E.; Professor Rankine, LL.D.; Mr. J. R. Napier, C.E.; Mr. R. Roberts, C.E.: Mr. Henry Wright to be Secretary.

That Professor James Thomson (of Belfast) be requested to continue his Experiments on the Gauging of Water; and that the sum of £10 be placed at his disposal for the purpose.

Applications for Reports and Researches.

That a Committee, consisting of Professor Walker, Prof. W. Thomson, Sir David Brewster, Dr. Sharpey, Dr. Lloyd, Colonel Sykes, General Sabine, and Prof. J. Forbes, be requested to report to the next Meeting at Oxford as to the scientific objects which may be sought for by continuing the Balloon Ascents formerly undertaken to great altitudes.

That Mr. A. Cayley be requested to continue his Report on the Solution of certain Special Problems in Dynamics.

That Dr. Dickie be requested to draw up a Report on the Flora of Ulster for the next Meeting of the Association.

That Dr. Carpenter be requested to draw up a Supplemental Report on the Minute Structure of Shells.

That the Committee on Patent Laws be reappointed, for the furtherance of the objects set forth in their Report presented to the Association at this Meeting.

That a Committee, consisting of Capt. Sir E. Belcher, C.B., Mr. G. Rennie, F.R.S., and Mr. W. Smith, with power to add to their number, be requested to report on the Rise and Progress of Steam Navigation in the Port of London.

That the following Members, viz. Mr. Thomas Webster, Prof. Willis, the Right Hon. Joseph Napier, Mr. Tite, M.P., Mr. William Fairbairn, Mr. Thos.

Graham, and General Sabine, be appointed a Committee for the furtherance of the objects set forth in the Report of the Patent Committee presented to the Association at this meeting, and that Mr. Webster be requested to act as Secretary to the same.

Involving Applications to Government or Public Institutions.

That the thanks of the British Association be offered to H.R.H. The Prince Consort, as President of the Association, for the interest he has manifested in the continuation of Magnetic Observations; and that he be requested, in concert with the President of the Royal Society, to take such steps as may appear most suitable to carry out the recommendation of the two Societies in respect to these observations.

That an Electrometer be constructed on the principle of that described by Professor W. Thomson. That it be verified at Kew, and a report of its performance be made to the Association at its next Meeting. That Professor W. Thomson be requested to carry this into effect, and that he be authorized to communicate with the President and Council of the Royal Society for the purpose of obtaining their cooperation.

The Committee of the Section of Mathematical and Physical Science having represented the probable importance of occasional telegraphic communication between a few widely-separated ports of Great Britain and Ireland, by which warning may be given of storms, the General Committee recommend application to the Board of Trade for such an arrangement as may further this object authoritatively.

That it is desirable that the British Association should express to Her Majesty's Government, through the proper authorities, its concurrence in the application made by the Royal Geographical Society to the First Lord of the Treasury, to further a proposed Expedition under Capt. Speke, to ascertain if the White Nile has its main source in the Great Nyanga Lake.

That in addition to the large and accurate Survey now in progress on the North-eastern coast of China, under the direction of the Admiralty, it is desirable to have prepared, with as little delay as possible, Maps on a smaller scale, and extending over a larger area.

Communications to be printed entire among the Reports.

Mr. Atherton.—On Steam-Transport Economy.

Mr. Fairbairn.—On Breaks for Railway Trains.

Mr. J. Park Harrison. — On Lunar Influence upon Temperature, with Diagrams.

Mr. A. Thomson—On Industrial Schools.

Mr. De la Rue.—Celestial Photography.

Professor Owen.—Classification of Reptiles.

Synopsis of Grants of Money appropriated to Scientific Objects by the General Committee at the Aberdeen Meeting in September 1859, *with the name of the Member, who alone, or as the First of a Committee, is entitled to draw for the Money.*

	£	s.	d.
Kew Observatory.			
At the disposal of the Council for defraying expenses	500	0	0
Chemical Science.			
SULLIVAN, Professor.—Solubility of Salts	30	0	0
VOELCKER, Professor.—Constituents of Manures	25	0	0
GAGES, ALPHONSE.—Chemico-Mechanical Analysis of Rocks	25	0	0
SMITH, Dr. ANGUS.—Scientific Evidence in Courts of Law ..	10	0	0
Geology.			
MALLET, ROBERT.—Earthquake Waves..................	25	0	0
ANDERSON, Rev. Dr.—Excavations in Yellow Sandstone of Dura Den	20	0	0
MURCHISON, Sir R. I.—Fossils in Upper Silurian Rocks, Lesmahago	15	0	0
Zoology and Botany.			
MACANDREW, ROBERT.—General Dredging	50	0	0
OGILVIE, Dr.—Dredging North and East Coasts of Scotland .	25	0	0
KINAHAN, Dr.—Dredging in Dublin Bay	15	0	0
DAUBENY, Dr.—Growth of Plants	10	0	0
Physiology.			
ALLMAN, Professor.—Report on Hydroid Zoophytes........	10	0	0
WILSON, Dr.—Colour-Blindness	10	0	0
Mechanical Science.			
MOORSOM, Admiral.—Steam-Vessels' Performance	150	0	0
THOMSON, Professor J.—Discharge of Water	10	0	0
Total....	£930	0	0

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

1834.

	£	s.	d.
Tide Discussions	20	0	0

1835.

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

1836.

	£	s.	d.
Tide Discussions	163	0	0
Briti sh ossil 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.

	£	s.	d.
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	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.

	£	s.	d.
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Subterranean Temperature	8	6	0
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	0
	£956	12	2

1839.

	£	s.	d.
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.

	£	s.	d.
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phænomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4

1841.

	£	s.	d.
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0

	£	s.	d.
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
ossil Reptiles	50	0	0
oreign 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.			
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.			
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations ...	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida..................................	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7
1853.			
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation..................	15	0	0
Researches on the British Annelida..................................	10	0	0
Dredging on the East Coast of Scotland.............................	10	0	0
Ethnological Queries	5	0	0
	£205	0	0
1854.			
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical 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.			
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

	£	s.	d.
1856.			
Maintaining the Establishment at Kew Observatory:— 1854......£ 75 0 0; 1855......£500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms...	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phænomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9
1857.			
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland..............................	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar..	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	£507	15	4
1858.			
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments..	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida...	25	0	0
Experiments on the production of Heat by Motion in Fluids ...	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2
1859.			
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds..................	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee...............	5	0	0
Steam Vessels' Performance......	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	0
Balloon Ascents......................	39	11	1
	£684	11	1

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. 14, at 8½ P.M., in the Music Hall, Richard Owen, M.D., D.C.L., F.R.S., Corr. Memb. Inst. of France, resigned the office of President to His Royal Highness the Prince Consort, who took the Chair and delivered an Address, for which see page lix.

On Thursday Evening, Sept. 15, a Conversazione took place in the Music Hall.

On Friday Evening, Sept. 16, at 8½ P.M., in the Music Hall, Sir R. I. Murchison, G.C.St.S., D.C.L., F.R.S., F.G.S., V.P.R.G.S., delivered a Discourse on the Geology of the Northern Highlands.

On Monday Evening, Sept. 19, at 8½ P.M., The Rev. T. Robinson, D.D., F.R.S., M.R.I.A., delivered a Discourse on Electrical Discharges in highly Rarefied Media.

On Tuesday Evening, Sept. 20, at 8½ P.M., a Conversazione took place in the Music Hall.

On Wednesday, Sept. 21, at 3 P.M., the concluding General Meeting took place in the Music 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 Oxford*.

* The Meeting is appointed to take place on Wednesday, the 27th of June, 1860.

ADDRESS

BY

HIS ROYAL HIGHNESS THE PRINCE CONSORT.

Gentlemen of the British Association,

Your kind invitation to me to undertake the office of your President for the ensuing year could not but startle me on its first announcement. The high position which Science occupies, the vast number of distinguished men who labour in her sacred cause, and whose achievements, while spreading innumerable benefits, justly attract the admiration of mankind, contrasted strongly in my mind with the consciousness of my own insignificance in this respect. I, a simple admirer, and would-be student of Science, to take the place of the chief and spokesman of the scientific men of the day, assembled in furtherance of their important objects!—the thing appeared to me impossible. Yet, on reflection, I came to the conclusion that, if not as a contributor to, or director of your labours, I might still be useful to you, useful to Science, by accepting your offer. Remembering that this Association is a popular Association, not a secret confraternity of men jealously guarding the mysteries of their profession, but inviting the uninitiated, the public at large, to join them, having as one of its objects to break down those imaginary and hurtful barriers which exist between men of science and so-called men of practice—I felt that I could, from the peculiar position in which Providence has placed me in this country, appear as the representative of that large public, which profits by and admires your exertions, but is unable actively to join in them; that my election was an act of humility on your part, which to reject would have looked like false humility, that is like pride, on mine. But I reflected further, and saw in my acceptance the means, of which necessarily so few are offered to Her Majesty, of testifying to you, through the instrumentality of her husband, that your labours are not unappreciated by your Sovereign, and that she wishes her people to know this as well as yourselves. Guided by these reflections, my choice was speedily made, for the path of duty lay straight before me.

If these, however, are the motives which have induced me to accept your flattering offer of the Presidency, a request on my part is hardly necessary that you will receive my efforts to fulfil its duties with kind indulgence.

If it were possible for anything to make me still more aware how much I stand in need of this indulgence, it is the recollection of the person whom I have to succeed as your President—a man of whom this country is justly proud, and whose name stands among the foremost of the Naturalists in Europe for his patience in investigation, conscientiousness in observation, boldness of imagination, and acuteness in reasoning. You have no doubt listened with pleasure to his parting address, and I beg to thank him for the flattering manner in which he has alluded to me in it.

The Association meets for the first time to-day in these regions and in this ancient and interesting city. The Poet, in his works of fiction, has to choose, and anxiously to weigh, where to lay his scene, knowing that, like the Painter, he is thus laying in the background of his picture, which will give tone and colour to the whole. The stern and dry reality of life is governed by the same laws, and we are here living, feeling, and thinking under the influence of the local impressions of this northern seaport. The choice appears to me a good one. The travelling Philosophers have had to come far, but in approaching the Highlands of Scotland they meet Nature in its wild and primitive form, and Nature is the object of their studies. The Geologist will not find many novelties in yonder mountains, because he will stand there on the bare backbone of the globe; but the Primary rocks, which stand out in their nakedness, exhibit the grandeur and beauty of their peculiar form, and in the splendid quarries of this neighbourhood are seen to peculiar advantage the closeness and hardness of their mass, and their inexhaustible supply for the use of man, made available by the application of new mechanical powers. On this primitive soil the Botanist and Zoologist will be attracted only by a limited range of plants and animals, but they are the very species which the extension of agriculture and increase of population are gradually driving out of many parts of the country. On those blue hills the red deer, in vast herds, holds undisturbed dominion over the wide heathery forest, until the sportsman, fatigued and unstrung by the busy life of the bustling town, invades the moor, to regain health and vigour by measuring his strength with that of the antlered monarch of the hill. But, notwithstanding all his efforts to overcome an antagonist possessed of such superiority of power, swiftness, caution, and keenness of all the senses, the sportsman would find himself baffled, had not Science supplied him with the telescope and those terrible weapons which seem daily to progress in the precision with which they carry the deadly bullet, mocking distance, to the mark.

In return for the help which Science has afforded him, the sportsman can supply the naturalist with many facts which he alone has opportunity of observing, and which may assist the solution of some interesting problems suggested by the life of the deer. Man also, the highest object of our study, is found in vigorous, healthy development, presenting a happy mixture of the Celt, Goth, Saxon, and Dane, acquiring his strength on the hills and the sea. The Aberdeen whaler braves the icy regions of the Polar Sea, to seek and to battle with the great monster of the deep: he has materially assisted in opening these icebound regions to the researches of Science; he fearlessly aided in the search after Sir John Franklin and his gallant companions, whom their country sent forth on this mission, but to whom Providence, alas! has denied the reward of their labours, the return to their homes, to the affectionate embrace of their families and friends, and the acknowledgments of a grateful nation. The City of Aberdeen itself is rich in interest for the Philosopher. Its two lately united Universities make it a seat of Learning and Science. The Collection of Antiquities, formed for the present occasion, enables him to dive into olden times, and, by contact with the remains of the handiworks of the ancient inhabitants of Scotland, to enter into the spirit of that peculiar and interesting people, which has always attracted the attention and touched the hearts of men accessible to the influence of heroic poetry. The Spalding Club, founded in this City for the preservation of the historical and literary remains of the north-eastern counties of Scotland, is honourably known by its important publications.

Gentlemen!—This is the 29th Anniversary of the foundation of this Association; and well may we look back with satisfaction to its operation and achievements throughout the time of its existence. When, on the 27th September, 1831, the Meeting of the Yorkshire Philosophical Society took place at York, in the theatre of the Yorkshire Museum, under the Presidency of the late Earl Fitzwilliam, then Viscount Milton, and the Rev. W. Vernon Harcourt eloquently set forth the plan for the formation of a British Association for the promotion of Science, which he showed to have become a want for his country, the most ardent supporter of this resolution could not have anticipated that it would start into life full-grown as it were, enter at once upon its career of usefulness, and pursue it without deviation from the original design, triumphing over the oppositions which it had to encounter in common with everything that is new and claims to be useful. Gentlemen, this proved that the want was a real, and not an imaginary one, and that the mode in which it was intended to supply that want was based upon a just appreciation of unalterable truths. Mr. Vernon Harcourt summed up the desiderata in graphic words, which have almost identically been retained as the exposition of the objects of the Society, printed at the head of the annually-appearing volume of its Transactions:—"to give a stronger impulse and more systematic direction to scientific inquiry—to promote the intercourse of those who cultivate Science in different parts of the Empire, with one another and with foreign Philosophers—and 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."

To define the nature of Science, to give an exact and complete definition of what that Science, to whose service the Association is devoted, is and means, has, as it naturally must, at all times occupied the Metaphysician. He has answered the question in various ways, more or less satisfactorily to himself or others. To me, Science, in its most general and comprehensive acceptation, means the knowledge of what I know, the consciousness of human knowledge. Hence, to know is the object of all Science; and all special knowledge, if brought to our consciousness in its separate distinctiveness from, and yet in its recognized relation to the totality of our knowledge, is scientific knowledge. We require, then, for Science—that is to say, for the acquisition of scientific knowledge—those two activities of our mind which are necessary for the acquisition of *any* knowledge—analysis and synthesis; the first, to dissect and reduce into its component parts the object to be investigated, and to render an accurate account to ourselves of the nature and qualities of these parts by observation; the second, to recompose the observed and understood parts into a unity in our consciousness, exactly answering to the object of our investigation. The labours of the man of Science are therefore at once the most humble and the loftiest which man can undertake. He only does what every little child does from its first awakening into life, and must do every moment of its existence; and yet he aims at the gradual approximation to divine truth itself. If, then, there exists no difference between the work of the man of Science and that of the merest child, what constitutes the distinction? Merely the conscious self-determination. The child observes what accident brings before it, and unconsciously forms its notion of it; the so-called practical man observes what his special work forces upon him, and he forms his notions upon it with reference to this particular work. The man of Science observes what he intends to observe, and knows why he intends it. The value which the peculiar object has in his eyes is not determined by accident, nor by an external cause, such as the mere connexion with work to be performed, but by the place which he knows this object to hold in the general universe of knowledge, by the relation which it bears to other parts of that general knowledge.

To *arrange* and *classify* that universe of knowledge becomes therefore the first, and perhaps the most important, object and duty of Science. It is only when brought into a system, by separating the incongruous and combining those elements in which we have been enabled to discover the internal connexion which the Almighty has implanted in them, that we can hope to grapple with the boundlessness of His creation, and with the laws which govern both mind and matter.

The operation of Science then has been, systematically to divide human knowledge, and raise, as it were, the separate groups of subjects for scientific consideration, into different and distinct sciences. The tendency to create new sciences is peculiarly apparent in our present age, and is perhaps inseparable from so rapid a progress as we have seen in our days; for the acquaintance with and mastering of distinct branches of knowledge enables the eye, from the newly gained points of sight, to see the new ramifications into which they divide themselves in strict consecutiveness and with logical necessity. But in thus gaining new centres of light, from which to direct our researches, and new and powerful means of adding to its ever-increasing treasures, Science approaches no nearer to the limits of its range, although travelling further and further from its original point of departure. For God's world is infinite; and the boundlessness of the universe, whose confines appear ever to retreat before our finite minds, strikes us no less with awe when, prying into the starry crowd of heaven, we find new worlds revealed to us by every increase in the power of the telescope, than when the microscope discloses to us in a drop of water, or an atom of dust, new worlds of life and animation, or the remains of such as have passed away.

Whilst the tendency to push systematic investigation in every direction enables the individual mind of man to bring all the power of which he is capable to bear on the specialities of his study, and enables a greater number of labourers to take part in the universal work, it may be feared that that consciousness of its unity which must pervade the whole of Science if it is not to lose its last and highest point of sight, may suffer. It has occasionally been given to rare intellects and the highest genius, to follow the various sciences in their divergent roads, and yet to preserve that point of sight from which alone their totality can be contemplated and directed. Yet how rare is the appearance of such gifted intellects! and if they be found at intervals, they remain still single individuals, with all the imperfections of human nature.

The only mode of supplying with any certainty this want, is to be sought in the combination of men of science representing all the specialities, and working together for the common object of preserving that unity and presiding over that general direction. This has been to some extent done in many countries by the establishment of academies embracing the whole range of the sciences, whether physical or metaphysical, historical or political. In the absence of such an institution in this country, all lovers of science must rejoice at the existence and activity of this Association, which embraces in its sphere of action, if not the whole range of the sciences, yet a very large and important section of them, those known as the *inductive sciences*, excluding all that are not approached by the inductive method of investigation. It has, for instance (and, considering its peculiar organization and mode of action, perhaps not unwisely), eliminated from its consideration and discussions those which come under the description of moral and political sciences. This has not been done from undervaluing their importance and denying their sacred right to the special attention of mankind, but from a desire to deal with those subjects only which can be reduced to positive proof, and do not rest on opinion or faith. The subjects of the moral and political sciences involve not only opinions but feelings; and their discussion frequently rouses passions. For feelings are "subjective," as the German metaphysician has it—they are inseparable from the individual being—an attack upon them is felt as one upon the person itself; whilst facts are "objective" and belong to everybody—they remain the same facts at all times and under all circumstances: they can be proved; they have to be proved, and when proved, are finally settled. It is with facts only that the Association deals. There may for a time exist differences of opinion on these also, but the process of removing them and resolving them into agreement is a different one from that in the moral and political sciences. These are generally approached by the *deductive* process; but if the reasoning be ever so acute and logically correct, and the point of departure, which may be arbitrarily selected, is disputed, no agreement is possible; whilst we proceed here by the *inductive* process, taking nothing on trust, nothing for granted, but reasoning upwards from the meanest fact established, and making every step sure before going one beyond it, like the engineer in his approaches to a fortress. We thus gain ultimately a roadway, a ladder by which even a child may, almost without knowing it, ascend to the summit of truth and obtain that immensely wide and extensive view which is spread below the feet of the astonished beholder. This road has been shown us by the great Bacon; and who can contemplate the prospects which it opens, without almost falling into a trance similar to that in which he allowed his imagination to wander over future ages of discovery!

From amongst the political sciences it has been attempted in modern times to detach one which admits of being severed from individual political opinions, and of being reduced to abstract laws derived from well authenticated facts. I mean Political Economy, based on general statistics. A new Association has recently been formed, imitating our perambulating habits, and striving to comprehend in its investigations and discussions even a still more extended range of subjects, in what is called "Social Science." These efforts deserve our warmest approbation and good will. May they succeed in obtaining a purely and strictly scientific character! Our own Association has, since its Meeting at Dublin, recognized the growing claims of Political Economy to scientific brotherhood, and admitted it into its Statistical Section. It could not have done so under abler guidance and happier auspices than the Presidency of the Archbishop of Dublin, Dr. Whately, whose efforts in this direction are so universally appreciated. But even in this Section, and whilst Statistics alone were treated in it, the Association as far back as 1833 made it a rule that, in order to ensure positive results, only those classes of facts should be admitted which were capable of being expressed by numbers, and which promised, when sufficiently multiplied, to indicate general laws.

If, then, the main object of Science—and I beg to be understood, henceforth, as speaking only of that Section which the Association has under its special care, viz. Inductive Science—if, I say, the object of science is the discovery of the laws which govern natural phænomena, the primary condition for its success is: accurate observation and collection of facts in such comprehensiveness and completeness as to furnish the philosopher with the necessary material from which to draw safe conclusions.

Science is not of yesterday. We stand on the shoulders of past ages, and the amount of observations made, and facts ascertained, has been transmitted to us and carefully preserved in the various storehouses of science; other crops have been reaped, but still lie scattered on the field; many a rich harvest is ripe for cutting, but waits for the reaper. Economy of labour is the essence of good husbandry, and no less so in the field of science. Our Association has felt the importance of this truth, and may well claim, as one of its principal merits, the constant endeavour to secure that economy.

One of the latest undertakings of the Association has been, in conjunction with the Royal Society, to attempt the compilation of a classified catalogue of scientific memoirs, which, by combining under one head the titles of all memoirs written on a certain subject, will, when completed, enable the student who wishes to gain information on that subject to do so with the greatest ease. It gives him, as it were, the plan of the house, and the key to the different apartments in which the treasures relating to his subject are stored, saving him at once a painful and laborious search, and affording him at the same time an assurance that what is here offered contains the whole of the treasures yet acquired.

While this has been one of its latest attempts, the Association has from its very beginning kept in view that its main sphere of usefulness lay in that concentrated attention to all scientific operations which a general gives to the movements of his army, watching and regulating the progress of his impetuous soldiers in the different directions to which their ardour may have led them, carefully noting the gaps which may arise from their independent and eccentric action, and attentively observing what impediments may have stopped, or may threaten to stop, the progress of certain columns.

Thus it attempts to fix and record the position and progress of the different labours, by its Reports on the state of Sciences published annually in its Transactions;—thus it directs the attention of the labourers to those gaps which require to be filled up, if the progress is to be a safe and steady one; —thus it comes forward with a helping hand in striving to remove those impediments which the unaided efforts of the individual labourer have been or may be unable to overcome.

Let us follow the activity of the Association in these three different directions.

The Reports on the state of Science originate in the conviction of the necessity for fixing, at given intervals, with accuracy and completeness, the position at which it has arrived. For this object the General Committee of the Association entrusts to distinguished individuals in the different branches of Science the charge of becoming, as it were, the biographers of the period. There are special points in different Sciences in which it sometimes appears desirable to the different Sections to have special reports elaborated; in such cases the General Committee, in its capacity of the representative assembly of all the Sciences, reserves to itself the right of judging what may be of sufficient importance to be thus recorded.

The special subjects which the Association points out for investigation, in order to supply the gaps which it may have observed, are—either such as the philosopher alone can successfully investigate, because they require the close attention of a practised observer, and a thorough knowledge of the particular subject; or they are such as require the greatest possible number of facts to be obtained. Here science often stands in need of the assistance of the general public, and gratefully accepts any contributions offered, provided the facts be accurately observed. In either case the Association points out *what* is to be observed, and *how* it is to be observed.

The first is the result of the same careful sifting process which the Association employs in directing the issue of special Reports. The investigations are entrusted to specially-appointed committees, or selected individuals. They are in most cases not unattended with considerable expense, and the Association, not content with merely suggesting and directing, furnishes by special grants the pecuniary means for defraying the outlay caused by the nature and extent of the inquiry. If we consider that the income of the Association is solely derived from the contributions of its members, the fact that no less a sum than £17,000 has, since its commencement, been thus granted for scientific purposes, is certainly most gratifying.

The question *how* to observe, resolves itself into two—that of the scientific method which is to be employed in approaching a problem or in making an observation, and that of the philosophical instruments used in the observation or experiment. The Association brings to bear the combined knowledge and experience of the scientific men, not only of this but of other countries, on the discovery of that method which, while it economizes time and labour, promises the most accurate results. The method to which, after careful examination, the palm has been awarded, is then placed at the free disposal and use of all scientific investigators. The Association also issues, where practicable, printed forms, merely requiring the different heads to be filled up, which, by their uniformity, become an important means for assisting the subsequent reduction of the observations for the abstraction of the laws which they may indicate.

At the same time most searching tests and inquiries are constantly carried on in the Observatory at Kew, given to the Association by Her Majesty, the object of which is practically to test the relative value of different methods and instruments, and to guide the constantly progressive improvements in the construction of the latter.

The establishment at Kew has undertaken the further important service of verifying and correcting to a fixed standard the instruments of any maker, to enable observations made with them to be reduced to the same numerical expression. I need hardly remind the inhabitants of Aberdeen that the Association, in one of the first years of its existence, undertook the comparative measurement of the Aberdeen standard scale with that of Greenwich,—a research ably carried out by the late Mr. Baily.

The impediments to the general progress of Science, the removal of which I have indicated as one of the tasks which the Association has set for itself, are of various kinds. If they were only such as direction, advice, and encouragement would enable the individual, or even combined efforts of philosophers, to overcome, the exertions of the Association which I have just alluded to might be sufficient for the purpose. But they are often such as can only be successfully dealt with by the powerful arm of the State or the long purse of the Nation. These impediments may be caused either by the social condition of the country itself, by restrictions arising out of peculiar laws, by the political separation of different countries, or by the magnitude of the undertakings being out of all proportion to the means and power of single individuals, of the Association, or even the voluntary efforts of the Public. In these cases the Association, together with its sister Society "the Royal Society," becomes the spokesman of Science with the Crown, the Government, or Parliament,—sometimes even, through the Home Government, with foreign Governments. Thus it obtained the establishment, by the British Government, of magnetic and meteorological observatories in six different parts of the globe, as the beginning of a network of stations which we must hope will be so far extended as to compass by their geographical distribution the whole of the phenomena which throw light on this important point in our tellurian and even cosmical existence. The Institute of France, at the recommendation of M. Arago, whose loss the scientific world must long deplore, cheerfully cooperated with our Council on this occasion. It was our Association which, in conjunction with the Royal Society, suggested the Antarctic Expedition with a view to further the discovery of the laws of terrestrial magnetism, and thus led to the discovery of the southern polar continent. It urged on the Admiralty the prosecution of the tidal observations, which that Department has since fully carried out. It recommended the establishment, in the British Museum, of the conchological collection exhibiting present and extinct species, which has now become an object of the greatest interest.

I will not weary you by further examples, with which most of you are better acquainted than I am myself, but merely express my satisfaction that there should exist bodies of men who will bring the well-considered and understood wants of Science before the public and the Government, who will even hand round the begging-box and expose themselves to refusals and rebuffs to which all beggars are liable, with the certainty, besides, of being considered great bores. Please to recollect that this species of bore is a most useful animal, well adapted for the ends for which Nature intended him. He alone, by constantly returning to the charge, and repeating the same truths and the same requests, succeeds in awakening attention to the cause which he advocates, and obtains that hearing which is granted him at last for self-protection, as the minor evil compared to his importunity, but which is requisite to make his cause understood. This is more particularly the case in a free, active, enterprising, and self-determining people like ours, where every interest works for itself, considers itself the all-important one, and makes its way in the world by its own efforts. Is it, then, to be wondered at, that the interests of Science, abstract as Science appears, and not immediately showing a return in pounds, shillings, and pence, should be postponed, at least, to others which promise immediate tangible results? Is it to be wondered at, that even our public men require an effort to wean themselves from other subjects in order to give their attention to Science and men of Science, when it is remembered that Science, with the exception of Mathematics, was until of late almost systematically excluded from our school and university education; —that the traditions of early life are those which make and leave the strongest impression on the human mind, and that the subjects with which we become acquainted, and to which our energies are devoted in youth, are those for which we retain the liveliest interest in after years, and that for these reasons the effort required must be both a mental and a moral one? A deep debt of gratitude is therefore due to bodies like this Association, which not only urges the wants of Science on the Government, but furnishes it at once with well-matured plans how to supply them with the greatest certainty and to the greatest public advantage.

We may be justified in hoping, however, that by the gradual diffusion of Science, and its increasing recognition as a principal part of our national education, the public in general, no less than the Legislature and the State, will more and more recognize the claims of Science to their attention; so that it may no longer require the begging-box, but speak to the State, like a favoured child to its parent, sure of his parental solicitude for its welfare; that the State will recognize in Science one of its elements of strength and prosperity, to foster which the clearest dictates of self-interest demand.

If the activity of this Association, such as I have endeavoured to describe it, ever found or could find its personification in one individual—its incarnation, as it were—this had been found in that distinguished and revered philosopher who has been removed from amongst us in his ninetieth year, within these last few months. Alexander von Humboldt incessantly strove after dominion over that universality of human knowledge which stands in need of thoughtful government and direction to preserve its integrity; he strove to tie up the *fasces* of scientific knowledge, to give them strength in unity. He treated all scientific men as members of one family, enthusiastically directing, fostering, and encouraging inquiry, where he saw either the want of, or the willingness for it. His protection of the young and ardent student led many to success in their pursuit. His personal influence with the Courts and Governments of most countries in Europe enabled him to plead the cause of

Science in a manner which made it more difficult for them to refuse than to grant what he requested. All lovers of science deeply mourn for the loss of such a man. Gentlemen, it is a singular coincidence, that this very day on which we are here assembled, and are thus giving expression to our admiration of him, should be the anniversary of his birth.

To return to ourselves, however: one part of the functions of the Association can receive no personal representation, no incarnation: I mean the very fact of meetings like that which we are at present inaugurating. This is not the thoughtful direction of one mind over acquired knowledge, but the production of new thought by the contact of many minds, as the spark is produced by the friction of flint and steel; it is not the action of the monarchy of a paternal Government, but the republican activity of the Roman Forum. These meetings draw forth the philosopher from the hidden recesses of his study, call in the wanderer over the field of science to meet his brethren, to lay before them the results of his labours, to set forth the deductions at which he has arrived, to ask for their examination, to maintain in the combat of debate the truth of his positions and the accuracy of his observations. These Meetings, unlike those of any other Society, throw open the arena to the cultivators of all sciences, to their mutual advantage: the Geologist learns from the Chemist that there are problems for which he had no clue, but which that science can solve for him; the Geographer receives light from the Naturalist, the Astronomer from the Physicist and Engineer, and so on. And all find a field upon which to meet the public at large, invite them to listen to their Reports and even to take part in their discussions,—show to them that Philosophers are not vain theorists, but essentially men of practice—not conceited pedants, wrapped up in their own mysterious importance, but humble inquirers after truth, proud only of what they may have achieved or won for the general use of man. Neither are they daring and presumptuous unbelievers—a character which ignorance has sometimes affixed to them—who would, like the Titans, storm heaven by placing mountain upon mountain, till hurled down from the height attained, by the terrible thunders of outraged Jove; but rather the pious pilgrims to the Holy Land, who toil on in search of the sacred shrine, in search of truth—God's truth—God's laws as manifested in His works, in His creation.

LIST OF PLATES.

PLATE I.

Illustrative of Mr. Norman Pogson's paper on three variable stars, R & S, Ursæ Majoris, and U Geminorum, as observed consecutively for six years.

PLATE II.

Illustrative of Mr. J. Park Harrison's paper on Lunar Influence on the Temperature of the Air.

PLATES III. IV. and V.

Illustrative of Mr. Balfour Stewart's paper on the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory.

PLATES VI. and VII.

Illustrative of Mr. Balfour Stewart's paper on the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken at the request of the British Association, by the late Mr. John Welsh.

ERRATA.

Page 4, line 10 from top, *for* Bayer *read* Bäyer.
Page 4, line 11 from bottom, *for* Bayer *read* Bäyer.
Page 6, note, *for* hyposulphuric acid *read* hyposulphurous acid.
Page 13, line 10 from top, *for* $C^2H^{18}N^2$ *read* $C^{21}H^{18}N^2$.
Page 14, line 8 from top, *for* glycocol † *read* glycocol.
Page 17, line 4 from bottom, *for* 3 Cl^2Zn *read* 3 ClZn.
Page 20, lines 6, 7 and 8 from top, *for* (ethylene, ... naphtaline, &c., by the action . . . . . simpler constitution. Synthesis of organic compounds)† *read* (ethylene, ... naphtaline, &c.) by the action of heat on organic substances of simpler constitution: synthesis of organic compounds †.
Page 20, line 11 from bottom, *for* Chloracetyl *read* Chloride of acetyl.
Page 22, last line, *for* $O=16$ and for $O^2=16$ *read* O=16 and $O^2=16$.
In the list of tribes, page 95, *for* Shopa *read* Lhopa; *for* Bagnath *read* Bagmati.
Page 99, *for* Shopa *read* Lhopa.
Page 100, *for* Bagnath *read* Bagmati.
Page 100, *for* Symbhunath Tribe (Hill-man, probably Thibetan) *read* Hill-man, probably Thibetan, obtained at Sambhunath.

REPORTS

ON

THE STATE OF SCIENCE.

REPORTS

ON

THE STATE OF SCIENCE.

Preliminary Report on the Recent Progress and Present State of Organic Chemistry. By George C. Foster, *B.A., F.C.S., Late Assistant in the Laboratory of University College, London.*

The late Mr. J. F. W. Johnston presented to the Second Meeting of this Association, held at Oxford in 1832, a "Report on the Recent Progress and Present State of Chemical Science." This Report included both Organic and Inorganic Chemistry, but no subsequent Report exists in which the progress of Organic Chemistry, as a whole, is discussed. It therefore seemed advisable to take the year 1832 as the starting-point of the Report, the preparation of which was entrusted to Dr. Odling and myself, at the Meeting in Leeds last year. On commencing the task, we found that a satisfactory account of the progress of organic chemistry, since that date, would be little else than a tolerably complete history of that branch of science. Believing that such a historical account would be of great value, we made some progress in its preparation. Those, however, who have the greatest acquaintance with the subject, will be the readiest to believe that it was utterly impossible for us to bring such a Report to anything like a state of completeness in time for the present Meeting. We thought, however, that such a general preliminary account as we might be able to give, of some of the most recent discoveries, illustrating some of the ideas most lately introduced into the science, might perhaps have both interest and utility.

In the following pages, therefore, in which such a general account is attempted, historical completeness has not been aimed at; the object has been rather to place in a clear light the real nature and tendency of some of the most important theoretical views which are now taking a place in the science.

The reconciling of the theory of types with the theory of compound radicles, which resulted from the discovery of the compound ammonias by Wurtz and Hofmann, and the discovery of the mixed ethers (or ethers containing two distinct alcohol-radicles) by Williamson, prepared the way for Gerhardt's classification of chemical substances according to types of double decomposition. The system of ideas, of which we may regard this classification as an epitome, has exerted so great an influence on the progress of theoretical chemistry during the last seven or eight years, that it becomes an essential part of a survey like the present to consider what parts of it have been modified or confirmed by recent discoveries.

Gerhardt's classification, like every classification which rests on chemical principles, was a system of *rational formulæ.* It is very important, therefore, for our present purpose, to understand clearly at the outset what his formulæ were intended to express. As he constantly repeated, they were not attempts to represent the arrangement of the atoms of chemical compounds, but to represent the groups or atoms, which, in the double decompositions by which compounds are formed or destroyed, replace, or are replaced by, other groups or atoms. His types were selected as being the simplest or best known bodies which could be the agents or products of double decompositions similar to those of the substances classified as deriving from them. Gerhardt's formulæ are, therefore, in the strictest sense chemical, and, as such, ought to be clearly distinguished from formulæ which are intended to express the molecular arrangement of compounds, formulæ which, speaking strictly, are physical, not chemical. The nature and importance of the distinction to which we refer will perhaps be made clearer if we recall to the recollection of the Section a recent instance in which it appears to have been overlooked by one of the ablest of living chemists. Gerhardt had given two different formulæ for aldehyde, namely, $C^2 H^3 O.H$ and $\left.\begin{matrix} C^2 H^3 \\ H \end{matrix}\right\} O$, each of which expresses accurately the chemical nature of aldehyde in relation to a particular set of reactions. Kopp, however, found that the specific gravity of aldehyde, calculated from the formula $C^2 H^3 O.H$, according to a rule which he had deduced from the examination of a considerable number of substances, agreed with the specific gravity found by experiment, but that the specific gravity calculated from the formula $\left.\begin{matrix} C^2 H^3 \\ H \end{matrix}\right\} O$ did not agree with experiment. He therefore concluded that the first formula was more accurate than the second. Assuming that the rule we have referred to was founded on a sufficient number of accurate observations, such a conclusion would doubtless be correct, were the formulæ intended as expressions of the molecular constitution of aldehyde so long as it remains such, that is to say, so long as its chemical characters do not come into account; but the facts in question have no bearing on the relative accuracy of formulæ which have reference solely to the reactions by which aldehyde can be formed or decomposed*.

The idea of polyatomic radicles and molecules naturally arose out of the attempt to represent polybasic acids according to types of decomposition. The first chemist who used formulæ expressing the replacement of more than one atom of hydrogen by a single atom of a compound radicle was Professor Williamson†. The views which he had expressed were extended, and the expression of them in chemical formulæ greatly facilitated, by the introduction, by Dr. Odling‡, of a special mode of notation. But the most numerous and most remarkable examples of polyatomic compounds hitherto known, have been furnished by the researches of Berthelot§ and of Wurtz‖.

In order to explain the nature of polyatomic compounds and the meaning of polyatomic formulæ, we cannot take a better illustration than the formula for glycerine proposed by Wurtz¶, $\left.\begin{matrix} (C^3 H^5)''' \\ H^3 \end{matrix}\right\} O^3$. This formula represents glycerine as deriving from three atoms of water by the substitution of the indivisible triatomic radicle $C^3 H^5$ for three atoms of hydrogen; that is to say, as a hydrate, but a hydrate which differs from ordinary hydrates, just as

* Comp. Kekulé, Ann. Chem. Pharm. cvi. 147, note.
† Chem. Soc. Quart. Journ. iv. 350.
‡ Ibid. vii. 1.
§ Ann. Chim. Phys. [3] xli. 216.
‖ Ibid. lv. 400.
¶ Ibid. xliii. 493.

a terchloride differs from a protochloride. Thus a protohydrate, alcohol, $\left.\begin{matrix} C^2 H^5 \\ H \end{matrix}\right\} O$, for example, is converted into a chloride by the action of one atom of hydrochloric acid, one atom of water being at the same time eliminated,—

$$\underset{\text{Alcohol.}}{\left.\begin{matrix} C^2 H^5 \\ H \end{matrix}\right\} O} + H\,Cl - H^2\,O = \underset{\text{Chloride of ethyl.}}{C^2\,H^5\,Cl},$$

and cannot then be any further acted on in the same way.

Glycerine is similarly converted into a chloride, with elimination of an atom of water, by the action of one atom of hydrochloric acid,

$$\underset{\text{Glycerine.}}{\left.\begin{matrix} C^3 H^5 \\ H^3 \end{matrix}\right\} O^3} + H\,Cl - H^2\,O = \underset{\text{Monochlorhydrin.}}{C^3\,H^7\,O^2\,Cl};$$

but the product in this case can again produce the same reaction with a second, and even with a third atom of hydrochloric acid:—

$$\underset{\text{Monochlorhydrin.}}{C^3\,H^7\,O^2\,Cl} + H\,Cl - H^2\,O = \underset{\text{Dichlorhydrin.}}{C^3\,H^6\,O\,Cl^2}$$

$$\underset{\text{Dichlorhydrin.}}{C^3\,H^6\,O\,Cl} + H\,Cl - H^2\,O = \underset{\text{Trichlorhydrin.}}{C^3\,H^5\,Cl^3}$$

And in general terms, we may express the difference between a polyatomic body and a monatomic body, deriving from the same type, by saying that, with the same reagent, both produce similar reactions, but that a greater quantity of the reagent (two, three, or four times as much, according as the substance is di-, tri-, or tetratomic) is required to react to the greatest possible extent with the polyatomic body than with the monatomic body.

The consideration of the following and similar series of bodies—

$C\,H^4$ .... Marsh-gas,
$C\,H^3\,Cl$ .... Chloride of methyl,
$C\,H^2\,Cl^2$ .... Chloride of methylene,
$C\,H\,Cl^3$ .... Chloroform,
$C\,Cl^4$ .... Bichloride of carbon,

throws great light upon the mutual relations of monatomic and polyatomic substances. The second term of the series is a monatomic chloride; it reacts with one atom, but not with more, of potash, ammonia, &c. The third is a diatomic* chloride, the fourth a triatomic† chloride, and the fifth a tetratomic‡ chloride. The radicles which these four chlorides respectively contain are $(CH^3)'$, $(CH^2)''$, $(CH)'''$, and $(C)^{iv}$, all formed from marsh-gas (CH^4), the first term of the series, by the removal of hydrogen; and the number of atoms of hydrogen which must be removed to form each radicle denotes the atomic value of that radicle. In other words, chloride of methyl, $CH^3\,Cl$, can, under a variety of conditions, part with its chlorine in exchange for other substances, whilst its carbon and hydrogen remain in unaltered combination, having the characters of a monatomic radicle. But, under certain other conditions, chloride of methyl can exchange one-third, two-thirds, or even the whole of its hydrogen against an equivalent quantity of chlorine; and the compounds which are formed, containing $C\,H^2\,Cl^2$, $C\,H\,Cl^3$, and $C\,Cl^4$,

* No reactions corresponding to this view of chloride of methylene are yet known, but the analogy of iodide of methylene (Comp. Buttlerow, Ann. Chim. Phys. [3] liii. 313) is sufficient for our present purpose.

† Comp. Kay, Chem. Soc. Quart. Journ. vii. 224; Hofmann, Proc. Roy. Soc. ix. 229.

‡ Comp. Hofmann, Proc. Roy. Soc. ix. 284.

can in their turn take up other substances in exchange for their chlorine, while the remainder of their elements (carbon, or carbon and hydrogen) pass into new compounds with the properties of polyatomic radicles.

These relations may be stated still more generally as follows:—compounds formed upon the molecular type CH^4 are either incapable of undergoing double decomposition, or are monatomic, diatomic, triatomic, or tetratomic, according to the number of atoms of hydrogen which are replaced, and to the nature of the substance by which it is replaced*.

A remarkable instance of a series of compounds presenting precisely similar relations has recently been pointed out by Bayer†, in his researches upon the compounds of methyl with arsenic.

If we now consider some of the most important reactions by which compounds are converted into others of greater atomic value, we shall find that in almost all cases the process is essentially the same as in those already referred to.

1. Acetic acid, $C^2 H^4 O^2$, which in most of its reactions behaves as a monatomic hydrate, is converted by the action of chlorine into chloracetic acid‡, $C^2 H^3 Cl O^2$. This substance can easily be made to part with its chlorine and to take up in its place other elements. For instance, when heated with an alkaline hydrate, it exchanges its chlorine against an atom of hydrogen and an atom of oxygen, thus—

$$\underset{\text{Chloracetic acid.}}{C^2 H^3 Cl O^2} + KHO = \underset{\text{Glycolic acid.}}{C^2 H^4 O^3} + KCl,$$

giving rise to an alkaline chloride and a biatomic acid, glycolic acid§. Again, chloracetic acid is decomposed by ammonia into hydrochloric acid and glycocol||, also a biatomic substance:—

$$\underset{\text{Chloracetic acid.}}{C^2 H^3 Cl O^2} + H^3 N = \underset{\text{Glycocol.}}{C^2 H^5 NO^2} + HCl.$$

In these two cases it admits of question whether the change from a monatomic to a diatomic compound takes place when the acetic acid is converted into chloracetic acid, or in the subsequent metamorphosis of the latter body. But at whatever stage of the process the change occurs, it is essentially the same, and consists in the replacement of an atom which, in ordinary double decompositions, acts as a constituent part of the radicle of the acid, by an atom or group which, in similar circumstances, acts as though it were external to the radicle.

2. Chloride of kakodyl, $AsMe^2 Cl$, is a monatomic chloride, but, acted upon by chlorine at the temperature of 40° to 50° C., it is converted into bichloride of arsenmonomethyl, $AsMeCl^2$, a diatomic chloride (Bayer). Here, again, the change may be described as the replacement of an atom (methyl) which is inactive with regard to double decompositions, by an atom (chlorine) which is active.

3. An increase in the quantity of oxygen contained in a compound generally increases its atomic value. An instance of this has already been referred to in the case of acetic and glycolic acids. We may mention as further examples—

Alcohol	$C^2 H^6 O$	Tritylic alcohol..	$C^3 H^8 O$	Monatomic.
Glycol	$C^2 H^6 O^2$	Tritylic glycol ..	$C^3 H^8 O^2$	Diatomic.
Ethyl-glycerine(?)	$C^2 H^6 O^3$	Glycerine	$C^3 H^8 O^3$	Triatomic.

* Comp. Odling, Journ. Roy. Instit., March 16th, 1855.
† Ann. Chem. Pharm. cv. 265; more fully, cvii. 257.
‡ R. Hoffmann, Ann. Chem. Pharm. cii. 1. § Kekulé, ibid. cv. 286.
|| Cahours, Ann. Chim. Phys. [3] liii. 355.

4. The conversion of benzoic, toluylic, cuminic, and anisic acids into the so-called benzamic, toluamic, cuminamic, and anisamic acids is a change equivalent to that of acetic acid into glycocol, and is therefore the change of a monatomic into a diatomic substance. We shall return hereafter to the consideration of the formulæ of glycocol and its analogues.

The following are examples of the transformation of polyatomic into monatomic compounds:—

1. Lactic acid, $C^3 H^6 O^3$ (diatomic), reacts with pentachloride of phosphorus, giving chloride of lactyl*, $C^3 H^4 O Cl^2$. Chloride of lactyl is decomposed by water into hydrochloric and chloro-propionic† acids,—

$$\underset{\text{Chloride of lactyl.}}{C^3 H^4 O Cl^2} + H^2 O = \underset{\text{Chloropropionic acid.}}{C^3 H^5 O^2 Cl} + H Cl,$$

and chloropropionic acid is converted by nascent hydrogen into propionic acid (monatomic). This transformation of lactic into propionic acid is evidently the converse of the transformation of acetic into glycolic acid which is mentioned above.

2. By similar reactions, salicylic acid, $C^7 H^6 O^3$ (diatomic), is converted into chloride of salicyl, $C^7 H^4 O Cl^2$, and into chlorobenzoic‡ acid, $C^7 H^5 O^2 Cl$.

3. The action of iodide of phosphorus on glycerine, $C^3 H^8 O^3$ (triatomic), gives iodopropylene, $C^3 H^5 I$, from which allylic alcohol, $C^3 H^6 O$ (monatomic), can be easily obtained.

Typical formulæ being representations of reactions, it follows that if a substance affords two or more distinct kinds of reactions, either of formation or of decomposition, it may be consistently represented by formulæ deriving from a corresponding number of distinct types.

Benzamide is a substance of this nature. Its formation by the reaction of chloride of benzoyle, or of benzoate of ethyl, upon ammonia, its decomposition by alkaline hydrates, and many other reactions, all characterize it as deriving from the type *ammonia*; accordingly it is commonly represented by the formula

$$\left.\begin{matrix} C^7 H^5 O \\ H \\ H \end{matrix}\right\} N.$$

But when acted upon by pentachloride of phosphorus, it is decomposed precisely as though it derived from the type *water*, and gives rise to the chloride of a radicle containing nitrogen, *chloride of benzamidyl*§, $C^7 H^6 N Cl$. The rational formula of benzamide which results from this reaction is

$$\left.\begin{matrix} C^7 H^6 N \\ H \end{matrix}\right\} O, \text{ deriving from the type } \left.\begin{matrix} H \\ H \end{matrix}\right\} O.$$

The substance described by Williamson ‖ as chlorohydrated sulphuric acid, $S H O^3 Cl$, may, in like manner, be represented either as a chloride or as a hydrate. Represented as a chloride¶, it takes its place in the following series of compounds containing the same radicle:—

Chloride .... $S H O^3, Cl$, Chlorohydrated sulphuric acid.

Hydrate .... $\left.\begin{matrix} S H O^3 \\ H \end{matrix}\right\} O$, Sulphuric acid.

* Wurtz, Ann. Chem. Pharm. cvii. 194.
† Ulrich, Ann. Chem. Pharm. cix. 268; Chem. Soc. Quart. Journ. xii. 23.
‡ Chiozza, Ann. Chim. Phys. [3] xxxvi. 102.
§ Gerhardt, Traité de Chimie Organique, iv. 762; Ann. Chim. Phys. [3] xlvi. 172.
‖ Proc. Roy. Soc. vii. 11. ¶ Comp. Schiff, Ann. Chem. Pharm. cii. 144.

Potassium-salt $\left.\begin{matrix} S\,H\,O^3 \\ K \end{matrix}\right\} O$, Acid sulphate of potassium.

Ether ...... $\left.\begin{matrix} S\,H\,O^3 \\ C^2\,H^5 \end{matrix}\right\} O$, Sulphovinic acid.

Amide...... $\left.\begin{matrix} S\,H\,O^3 \\ H \\ H \end{matrix}\right\} N$, Sulphamic acid.

Represented as a hydrate, it becomes $\left.\begin{matrix} S\,Cl\,O^2 \\ H \end{matrix}\right\} O$, and enters into the following series:—

Chloride .... $S\,Cl\,O^2, Cl$, Chlorosulphuric acid.

Hydrate ..... $\left.\begin{matrix} S\,Cl\,O^2 \\ H \end{matrix}\right\} O$, Chlorohydrated sulphuric acid.

Potassium-salt $\left.\begin{matrix} S\,Cl\,O^2 \\ K \end{matrix}\right\} O$, Rose's sulphate of chloride of potassium.

Ether........ $\left.\begin{matrix} S\,Cl\,O^2 \\ C^2\,H^5 \end{matrix}\right\} O$, Chlorethylated sulphuric acid*.

But the rational formula which Williamson gave for his compound was neither of these, but a combination of them into one; namely,

$$\left.\begin{matrix} \left.\begin{matrix} Cl \\ SO^2 \end{matrix}\right\} \\ \left.\begin{matrix} SO^2 \\ H \end{matrix}\right\} O. \end{matrix}\right.$$

This formula represents a substance at once a hydrate and a chloride, formed from the double type $\left.\begin{matrix} \left.\begin{matrix} Cl \\ H \end{matrix}\right\} \\ \left.\begin{matrix} H \\ H \end{matrix}\right\} O, \end{matrix}\right.$ the two atoms of which are held together by the diatomic radicle $S\,O^2$ replacing one atom hydrogen in each. It is obvious that a substance so constituted would react either as a chloride or as a hydrate, according to the nature of the substances with which it was brought in contact.

Until the discovery of chlorohydrated sulphuric acid, the idea of polyatomic radicles was confined to the replacement of two or more atoms of hydrogen in one or more molecules of a single typical substance. The notion of *mixed types*, of which this substance afforded the earliest† illustration, has been applied by Kekulé‡, with remarkable ability, to explain the constitution of a great number of highly complex substances.

Every substance which can be represented by a formula deriving from a mixed type may also be represented by two or more formulæ, each deriving from a simple type, but containing a comparatively complex radicle. In all cases the choice is open between complex types with simple radicles, and simple types with complex radicles§.

* R. Williamson, Chem. Soc. Quart. Journ. x. 97.

† Odling, in a paper already quoted (Chem. Soc. Quart. Journ. vii.), represented hyposulphuric acid as $\left.\begin{matrix} \left.\begin{matrix} H \\ SO^2 \end{matrix}\right\} S \\ \left.\begin{matrix} SO^2 \\ H \end{matrix}\right\} O \end{matrix}\right.$ deriving from the type $\left.\begin{matrix} H^2\,S \\ H^2\,O \end{matrix}\right\}$, which, however, may be regarded as a mere variation of the type $\left.\begin{matrix} H^2\,O \\ H^2\,O \end{matrix}\right\}$.

‡ Ann. Chem. Pharm. civ. 129.

§ Comp. Kopp, Jahresber. 1857, 271.

We may illustrate this by reference to a substance which has been mentioned above; namely, benzamide. We have shown how, according to the particular reactions which we take into consideration, benzamide may be regarded either as a nitride or as an oxide; as $\left.\begin{matrix} C^7H^5O \\ H \\ H \end{matrix}\right\}N$, or as $\left.\begin{matrix} C^7H^6N \\ H \end{matrix}\right\}O$.

Both of these formulæ derive from very simple types, but each contains a somewhat complex radicle,—a radicle containing three different elements. If, however, we combine these two expressions, and, by means of a polyatomic radicle, represent benzamide as deriving from the mixed type $\left.\begin{matrix} H^3N \\ H^2O \end{matrix}\right\}$,

we obtain the formula $\begin{matrix} H \\ (C^7H^5)''' \\ H \end{matrix}\begin{matrix} \}N \\ \\ \}O \end{matrix}$.

This is a more general expression than either of the other two, for it gives us even more information as to the possible transformations and derivatives of benzamide than both of them taken together. Corresponding formulæ for the other members of the benzoic group may be obtained from it by supposing the water or ammonia of the type replaced by other molecules. For example:—

Benzoic acid .... $\left.\begin{matrix} (C^7H^5)'''O \\ H \quad O \end{matrix}\right\}$, type $\left[\begin{matrix} \left.\begin{matrix} H \\ H \end{matrix}\right\}O \\ \left.\begin{matrix} H \\ H \end{matrix}\right\}O \end{matrix}\right.$,

Chloride of benzoyl............ $(C^7H^5)'''\left\{\begin{matrix} Cl \\ O \end{matrix}\right.$, type $\left[\begin{matrix} HCl \\ H^2O \end{matrix}\right.$,

Chloride of benzamidyl .... $\left.\begin{matrix} H \\ (C^7H^5)''' \\ Cl \end{matrix}\right\} N$, type $\begin{matrix} \left.\begin{matrix} H \\ \left[\begin{matrix} H \\ H \\ H \end{matrix}\right. \end{matrix}\right\} N \\ Cl \end{matrix}$,

Unknown analogue of acediamine $\begin{matrix} H \\ (C^7H^5)''' \\ H \\ H \end{matrix}\begin{matrix} \}N \\ \\ \}N \end{matrix}$, type $\left[\begin{matrix} \left.\begin{matrix} H \\ H^2 \end{matrix}\right\}N \\ \left.\begin{matrix} H \\ H \\ H \end{matrix}\right\}N \end{matrix}\right.$,

Product of the action of pentachloride of phosphorus on chloride of benzoyl*.. $(C^7H^5)'''\left\{\begin{matrix} Cl \\ Cl \\ Cl \end{matrix}\right.$, type $\left[\begin{matrix} HCl \\ HCl \\ HCl \end{matrix}\right.$,

Benzonitrile.................. $(C^7H^5)'''\ N$, type H^3N.

In all cases, formulæ derived from complex types and containing simple radicles, are of a higher degree of generality than formulæ derived from simple types and containing complex radicles. This will become evident if we consider a little the real import of types and radicles. It is clear, in the first place, that a formula derived from a single molecule of any given type, only tells us that the body which it represents can undergo once over the decompositions which characterize that particular type. If we want to express that it can undergo the same decomposition twice or three times, we must represent it as deriving from two, or from three molecules of the same type. Or, if we want to express that it can undergo decompositions of two

* Schischkoff & Rosing, Compt. Rend. xlvi. 367; Jahresber. 1858, 279.

or more distinct kinds, we must give to it a formula derived from the combination of the types corresponding to the decompositions in question; that is to say, the more numerous are the reactions which we take into account in constructing the rational formula of any substance, the more complex must be the type from which that formula is derived. Secondly, it is obvious that complication of type involves simplification of radicles; for in any compound, the greater the number of atoms which are regarded as belonging to the type, the smaller the number left to constitute the radicle.

We see therefore that rational formulæ of the highest possible degree of generality would contain radicles of the greatest possible degree of simplicity; that is, consisting of *single atoms of the elementary bodies.* And in the case of every compound of which our knowledge is extensive enough for us to be able to trace, through a series of reactions which affect it more and more deeply, the successive separation of all its atoms, one from another, or the process of the recombination of these atoms into the original compound, the rational formula, which would express the sum of our knowledge respecting it, would actually take the form we have mentioned.

In illustration of these remarks, we may consider briefly the known reactions of acetic acid, and the way in which they may be expressed by rational formulæ.

1. The relation of acetic acid to the acetates shows that it contains an atom of hydrogen which can be separated from the other atoms. The rational formula expressing this is

$$C^2 H^3 O^2 . H.$$

2. In the decomposition of acetic acid by pentachloride of phosphorus, and by pentasulphide of phosphorus, as well as in its conversion into acetamide, one half of its oxygen is separated from it. Considering this result in connexion with the formula deduced in (1), we obtain the formula

$$C^2 H^3 O . H . O, \qquad \text{or} \qquad \begin{matrix} C^2 H^3 O \\ H \end{matrix} O;$$

which expresses that an atom of hydrogen, or an atom of oxygen, or both together, may be separated from acetic acid, while the rest of its atoms remain combined.

3. Acediamine, $C^2 H^6 N^2$ *, acetonitrile, $C^2 H^3 N$, and the substance $C^2 H^3 Cl^3$ (formerly terchloride of acetyl, but now without a name), are derivatives of acetic acid in which it is represented by the triatomic radicle $C^2 H^3$. Hence the last formula must be replaced by

$$\begin{matrix} (C^2 H^3)''' & O \\ H & O \end{matrix}, \text{ derived from the type } \left.\begin{matrix} H^2 O \\ H^2 O \end{matrix}\right\}.$$

4. There are many reactions in which a compound belonging to the carbonic group and one belonging to the methylic group are formed simultaneously from acetic acid or one of its derivatives, or in which an acetic compound is formed synthetically from a compound of the carbonic group and one of the methylic group. We may mention—

(A) of decompositions, the formation of a carbonate and acetone by the distillation of an alkaline acetate by itself, or of a carbonate and marsh-gas when it is distilled with an alkaline hydrate; the electrolytic decomposition of acetic acid; the formation of kakodyle; the production of disulphometholic acid and carbonic anhydride by the action of fuming sulphuric acid on acetonitrile†; the decomposition of glycocol

* Strecker, Ann. Chem. Pharm. ciii. 328.

† Buckton and Hofmann, Chem. Soc. Quart. Journ. ix. 243; Ann. Chem. Pharm. c. 133.

when distilled with baryta, into methylamine and carbonate of barium*:

(B) of formations, the production of acetate of sodium from sodium-methyl and carbonic anhydride†; of acetonitrile from iodide of methyl or methyl-sulphate of potassium and cyanide of potassium.

To indicate the possibility of these reactions, we must break up the radicle C^2H^3, contained in the last formula, into $C.CH^3$. The formula of acetic acid will then be

$$(C)^{iv}\left\{\begin{array}{l} CH^3 \\ \}O \\ H\}O \end{array}\right.$$

derived from the type $\left[\begin{array}{l} \overbrace{HH} \\ \left.\begin{array}{l} H \\ H \end{array}\right\} O \\ \left.\begin{array}{l} H \\ H \end{array}\right\} O \end{array}\right.$ by the replacement of one atom of hydrogen in the type $\overbrace{HH}$ by the monatomic radicle CH^3, and the replacement of the other atom together with all the hydrogen of one atom H^2O, and half the hydrogen in the second atom H^2O, by the tetratomic radicle $(C)^{iv}$.

5. The addition of one atom oxygen to the molecule of acetic acid has the effect of rendering a second atom of hydrogen (see 1) separable from the rest (production of glycolide, action of pentachloride of phosphorus)‡. We can express this by the formula

$$(C)^{iv}\left\{\begin{array}{l} H\}(CH^2)'' \\ \}O \\ H\}O \end{array}\right.$$

derived from the type

$$\left[\begin{array}{l} \overbrace{HH} \\ \overbrace{HH} \\ \left.\begin{array}{l} H \\ H \end{array}\right\} O \\ \left.\begin{array}{l} H \\ H \end{array}\right\} O \end{array}\right.$$

The addition of one atom oxygen to this formula would convert one of the molecules of HH in the type into H^2O. The formula of glycolic acid, the substance formed by combining acetic acid with an atom of oxygen, would therefore be

$$(C)^{iv}\left\{\begin{array}{l} \overbrace{H\ (CH^2)''}^{O} \\ \}O \\ H\}O \end{array}\right. \quad \text{derived from} \quad \left[\begin{array}{l} \overbrace{HH}^{O} \\ \overbrace{HH} \\ \left.\begin{array}{l} H \\ H \end{array}\right\} O \\ \left.\begin{array}{l} H \\ H \end{array}\right\} O. \end{array}\right.$$

* Cahours, Ann. Chim. Phys. (3) liii. 353. † Wanklyn, Ann. Chem. Pharm. cxi. 234.

‡ Acetic acid + 1 atom oxygen = glycolic acid. We may venture to affirm that glycolic acid would react like lactic acid with pentachloride of phosphorus.

6. The addition of two atoms of oxygen to acetic acid produces a homologue of glyceric acid, containing $C^2 H^4 O^4$*. We are justified by analogy in assuming that in this compound three out of the four atoms of hydrogen are separable from the carbon. The possible production of such a compound is indicated by the formula

$$\begin{array}{l} \quad\left.\begin{array}{l}H\\H\end{array}\right\}(CH)''' \\ (C)^{iv}\left\{\begin{array}{l} \quad\}O \\ H\}O\end{array}\right. \end{array} \quad \text{derived from} \quad \left[\begin{array}{l}\overbrace{H\,H}\\ \overbrace{H\,H}\\ \overbrace{H\,H}\\ \left.\begin{array}{l}H\\H\end{array}\right\}O\\ \left.\begin{array}{l}H\\H\end{array}\right\}O.\end{array}\right.$$

7. The last formula expresses every possible decomposition of acetic acid except the complete separation of its carbon and hydrogen, which occurs when $\frac{1}{4}$ of the latter is replaced by a metal and the remaining $\frac{3}{4}$ by chlorine, as in a metallic terchloracetate, or when acetic acid is completely oxidized into carbonic anhydride and water. To express such reactions as these, in connexion with those already considered, acetic acid must be represented as built up of separate elementary atoms, without the subordinate combination of even two of them into a compound radicle. For in the reactions which have been enumerated, all the atoms of which acetic acid is composed, are one by one separated from each other; so that not one of them remains combined directly or indirectly with any of the rest. Hence the formula at which we finally arrive, the most general that it is possible to give, is the following:—

$$\begin{array}{l} \quad\left.\begin{array}{l}H\\H\\H\end{array}\right\}(C)^{iv} \\ (C)^{iv}\left\{\begin{array}{l} \quad\}(O)'' \\ H\}(O)''\end{array}\right. \end{array} \quad \text{derived from} \quad \left[\begin{array}{l}\overbrace{H\,H}\\ \overbrace{H\,H}\\ \overbrace{H\,H}\\ \overbrace{H\,H}\\ \left.\begin{array}{l}H\\H\end{array}\right\}O\\ \left.\begin{array}{l}H\\H\end{array}\right\}O\end{array}\right.$$

or one of equivalent meaning.

In this formula all the atoms are represented as entering into combination on an equal footing, and each in turn may be regarded as a radicle or part of the type.

Before leaving the subject, it is worth while to point out that each set of relations which we have successively considered, in order to generalize more and more the formula of acetic acid, has in its turn been made the foundation of a separate rational formula.

Upon the binary theory of acids, acetic acid receives the formula $C^2 H^3 O^2 . H$, which is the same in form and meaning as that given in (1). The formula given by Williamson and Gerhardt (2) was intended to express the relation of acetic acid to chloride of acetyl, acetamide, &c. Liebig's for-

* Perkin and Duppa, Chem. Soc. Quart. Journ. xii. 6.

mula, $C^4 H^3, O^3 . HO$*, indicates its connexion with $C^4 H^3 Cl^3$* (the old terchloride of acetyl), aldehyde and other substances containing $C^4 H^3$* (3)†. Reactions of the kind mentioned in (4) led Kolbe to adopt the formula $HO.(C^2 H^3)C^2, O^3$*. Dumas wrote acetic acid $C^4 \overset{H}{\underset{H}{H}} O^3 . HO$*, to express that that portion of the hydrogen which cannot be replaced by metals, can be removed and replaced by other elements, *e. g.* chlorine (5, 6, and 7). The formula which we have given as the most general of all is nothing more than a combination of all these, and therefore enables us to recognize the value of each‡.

Similar considerations applied to any of the derivatives of acetic acid would lead us to adopt for them formulæ of the same degree of generality; for instance, for chloride of acetyl,—

$$\begin{array}{l} \left.\begin{array}{l} \mathrm{H} \\ \mathrm{H} \\ \mathrm{H} \end{array}\right\} (\mathrm{C})^{\mathrm{iv}} \\ (\mathrm{C})^{\mathrm{iv}}\left\{\begin{array}{l} \}\mathrm{O} \\ \mathrm{Cl} \end{array}\right. \end{array} \text{, and for acetamide } \begin{array}{l} \left.\begin{array}{l} \mathrm{H} \\ \mathrm{H} \\ \mathrm{H} \end{array}\right\} (\mathrm{C})^{\mathrm{iv}} \\ (\mathrm{C})^{\mathrm{iv}}\left\{\begin{array}{l} \}(\mathrm{O})'' \\ \left.\begin{array}{l} \mathrm{H} \\ \mathrm{H} \end{array}\right\}(\mathrm{N})''' \end{array}\right. \end{array}.$$

And in proportion as our knowledge of the genetic relations of any class of compounds is increased, so will their rational formulæ approach more and more nearly to the same form. All formulæ which come short of this are but imperfect descriptions of the bodies which they represent; for it is evident that a formula containing a compound radicle cannot represent reactions in which the elements composing that radicle are separated from each other. Nevertheless, for the expression of those relations with which we are most frequently concerned, and for the purposes of classification, it would be of no advantage that the most general formulæ should be employed. The relation between any two compounds is best expressed by whatever particular abbreviations of the general formulæ represent most simply and distinctly the extent of their similarity and difference; while, for purposes of classification, it is essential that all bodies should receive formulæ of a comparable degree of generality; and in the majority of cases, the possible degree of generality is but small. Hence Gerhardt's formulæ, since they express just those reactions with which we are most familiar, and can be applied to every compound of which we can be said to have any chemical knowledge at all, are better adapted than any others to the ordinary requirements of science in its present state.

On the other hand, it cannot be doubted that the chemical character of every substance is affected in a certain definite degree by each separate atom that it contains. And the only way by which we can hope ultimately to ascertain the true chemical value of the elements, or, in other words, to trace the full connexion between the properties and composition of compounds, is by comparing, when possible, (what we may call) their *elementary formulæ*. Moreover, we ought not to forget that any classification of chemical compounds, which is not founded upon the consideration of their *elementary formulæ*, that is, upon the consideration of their *total* reactions, however

* $C = 6, H = 1, O = 8$.

† Schischkoff, Ann. Chim. Phys. [3] xlix. 355, has represented acetic acid by precisely the same formula as that given in (3).

‡ For a list of nineteen different formulæ for acetic acid, see Kekulé, Lehrb. d. Organ. Chem., p. 58.

well it may correspond to any particular stage in the development of science, can never be more than a temporary expedient, which must be replaced sooner or later by a classification framed according to more general principles.

The discoveries which have led to, or resulted from, the development of the theory of polyatomic radicles, have caused a corresponding extension of our notion of a chemical family or group. The principal relations of composition which have hitherto been observed among compounds of the same natural family and deriving from the same type, may be expressed by the following formulæ, in which n and x are always whole numbers and n always greater than x:—

$$1.\ C^n H^{2(n+1-x)} O,\quad 4.\ C^n H^{2(n-x)} O^2,\quad 7.\ C^n H^{2(n-\overline{x+1})} O^3,\quad 10.\ C^n H^{2(n-\overline{x+2})} O^4,$$

$$2.\ C^n H^{2(n+1-x)} O^2,\quad 5.\ C^n H^{2(n-x)} O^3,\quad 8.\ C^n H^{2(n-\overline{x+1})} O^4,\quad 11.\ C^n H^{2(n-\overline{x+2})} O^5,$$

$$3.\ C^n H^{2(n+1-n)} O^3,\quad 6.\ C^n H^{2(n-x)} O^4,\quad 9.\ C^n H^{2(n-\overline{x+1})} O^5,\quad 12.\ C^n H^{2(n-\overline{x+2})} O^6.$$

As a special example we may take the tritylic (or propionic) group, in which as yet the number of known terms is more numerous than in any other. Here $n=3$, $x=0$, and the above formulæ become

1. $C^3 H^8 O$ Tritylic alcohol.	4. $C^3 H^6 O^2$ Propionic acid.	7. $C^3 H^4 O^3$ Pyruvic acid.	10. $C^3 H^2 O^4$?
2. $C^3 H^8 O^2$ Tritylic glycol.	5. $C^3 H^6 O^3$ Lactic acid.	8. $C^3 H^4 O^4$ Malonic acid.	11. $C^3 H^2 O^5$ Mesoxalic acid.
3. $C^3 H^8 O^3$ Glycerine.	6. $C^3 H^6 O^4$ Glyceric acid.	9. $C^3 H^4 O^5$ Tartronic acid.	12. $C^3 H^2 O^6$?

The substances which these formulæ express are all hydrates,—alcohols or acids. It will easily be understood that around each of them, considered as a primary compound, a large number of derivatives,—ethers, anhydrides, chlorides, nitrides, &c.—will arrange themselves. Thus, formula 1 represents, primarily, the *monatomic alcohols*. To the list of bodies belonging to this class Berthelot* has recently added cholesterine, $C^{26} H^{44} O$ ($n=26, x=5$) (?), and Borneo camphor or camphol, $C^{10} H^{18} O$ ($n=10$, $x=2$). The first of these substances is homologous with cinnamic alcohol, $C^9 H^{10} O$; the second is as yet without homologues. Secondarily, it represents all bodies which may be supposed to contain the same radicles as any actual or possible monatomic alcohols. Here, therefore, come the simple and double ethers, the chlorides, iodides and the like derived from monatomic alcohols; also the corresponding alkalies containing nitrogen, phosphorus, or arsenic; compounds containing metals, as kakodyl, zinc-ethyl, &c., and many other bodies which these will serve to suggest.

Formula 2 (derived from 1 by the addition of an atom of oxygen) represents the diatomic alcohols or glycols, and such other substances as may be supposed to contain similar diatomic radicles. The substances belonging to this class are—

(A) the glycols†, of which there are already known ethyl-glycol, $C^2 H^6 O^2$, propyl-glycol, $C^3 H^8 O^2$, butyl-glycol, $C^4 H^{10} O^2$, amyl-glycol, $C^5 H^{12} O^2$, probably also anisic alcohol‡, $C^8 H^{10} O^2$, and saligenine,

* Ann. Chim. Phys. [3] lvi. 51 (1859).
† Wurtz, Ann. Chim. Phys. [3] lv. 400.
‡ Cannizzaro and Bertagnini, Ann. Chem. Pharm. xcviii. 188; Chem. Soc. Quart. Journ. ix. 190.

$C^7 H^8 O^2$, and derivatives from them containing the same radicles; and (B) certain substances which behave as though they contained diatomic alcohol-radicles, although the corresponding alcohols have not yet been obtained. Among these latter we may mention iodide and biacetate of methylene*; the substances obtained by Wicke† and by Engelhardt‡ from chlorobenzol, substances which appear to be the methylate, ethylate, acetate, valerate, benzoate, &c. corresponding to a still unknown diatomic alcohol, $\left.\begin{matrix} C^7 H^6 \\ H^2 \end{matrix}\right\} O^2$, isomeric (or identical?) with saligenine, to which it also seems probable, from the experiments of Engelhardt§ and Borodine‖, that hydrobenzamide, $C^2 H^{18} N^2$, stands in the same relation that, as has been shown by Hofmann¶, Cloëz's so-called propylia (properly terethylenamine) does to glycol, or as terethylamine does to alcohol.

Formula 3 (derived from 2 by the addition of an atom of oxygen) is representative of glycerine, its derivatives, and their analogues. Among compounds comparable to the derivatives of glycerine are chloroform and analogous substances, such as terchloride of acetyl, $C^2 H^3 Cl^3$, and the substance $C^4 H^7 Br^3$ obtained by the action of excess of bromide of phosphorus on butyric acid**; also the cyanides of the alcohol-radicles if regarded as derivatives of ammonia; acediamine, $\left.\begin{matrix} (C^2 H^3)''' \\ H^3 \end{matrix}\right\} N^2$; Schischkoff's†† ternitroaceto-nitrile, $(C^2 (NO^2)^3)''' N$, and the substance formed from it by the action of sulphydric acid, having the composition of binitro-acediamine, $\left.\begin{matrix} (C^2 H (NO^2)^2)''' \\ H^3 \end{matrix}\right\} N^2$ ("*Dinitrammonyl der Essigsäurereihe*"), and various substances formed by the reaction of pentachloride of phosphorus with monatomic amides, which will be referred to hereafter.

Formula 4 (derived from 1 by the substitution of O for H^2) represents monobasic acids containing O^2, such as the acids of the acetic, acrylic and benzoic series and their derivatives. To this class of bodies there has been lately added by Dr. Hofmann‡‡, sorbic acid, $C^6 H^8 O^2$ ($n=6$, $x=2$).

Formula 5 (derived from 4 by the addition of an atom of oxygen) represents the acids homologous with carbonic acid, namely glycolic, $C^2 H^4 O^3$, lactic, $C^3 H^6 O^3$, &c., and acids analogous to these, such as oxybenzoic, $C^7 H^6 O^3$, with their derivatives. The list of these acids has recently been increased by the addition of glyoxylic§§ acid, $C^2 H^2 O^3$ ($n=2, x=1$), butylactic acid‖‖, $C^4 H^8 O^3$ ($n=4$, $x=0$), and oxycuminic¶¶ $C^{10} H^{12} O^3$ ($n=10$, $x=4$).

Among their derivatives are benzo-glycolic acid, $\left.\begin{matrix} (C^2 H^2 O)'' \\ C^7 H^5 O \\ H \end{matrix}\right\} O^2$, benzo-lactic acid, $\left.\begin{matrix} (C^3 H^4 O)'' \\ C^7 H^5 O \\ H \end{matrix}\right\} O^2$, and, in a certain sense, such acids as chloracetic,

* Buttlerow, Ann. Chim. Phys. [3] liii. 313.
† Ann. Chem. Pharm. cii. 356.
‡ Chem. Gaz. 1857, 424.
§ Ann. Chem. Pharm. cx. 77.
‖ Ibid. 78.
¶ Proc. Roy. Soc. ix. 150.
** Berthelot, Jahresber. 1858, 280.
†† Ann. Chim. Phys. [3] xlix. 320. Schischkoff and Rosing, Ann. Chem. Pharm. civ. 249.
‡‡ Chem. Soc. Quart. Journ. xii. 43.
§§ Debus, Ann. Chem. Pharm. c. 1; cii. 29.
‖‖ Wurtz, Ann. Chem. Pharm. cvii. 197; Ann. Chim. Phys. [3] lv. 456, 460.
¶¶ Cahours, Ann. Chim. Phys. [3] liii. 338.

$$\left(C^2H^3ClO^2=\begin{array}{l}\quad Cl\ \Big\}\\ (C^2H^2O)''\\ \quad H\quad\Big\}O\end{array}\right),\ \text{chlorobenzoic},\ \left(C^7H^5ClO^2=\begin{array}{l}\quad Cl\ \Big\}\\ (C^7H^4O)''\\ \quad H\quad\Big\}O\end{array}\right),$$

$$\text{sulphacetic*},\ \left(C^2H^4SO^5=\begin{array}{l}\quad H\quad\ \Big\}O\\ (C^2H^2O)''\Big\}\\ \ (SO^2)''\\ \quad H\quad\ \Big\}O\end{array}\right)\ \text{and}$$

$$\text{sulphobenzoic*},\ \left(C^7H^6SO^5=\begin{array}{l}\quad H\quad\ \Big\}O\\ (C^7H^4O)''\Big\}\\ \ (SO^2)''\\ \quad H\quad\ \Big\}O\end{array}\right);\ \text{also glycocol,}$$

alanine, leucine, benzamic acid, toluamic acid, cuminamic acid, &c. These last-mentioned substances are intermediate in their properties between derivatives of the type H^2O and those of the type H^3N; they must therefore be regarded as deriving from the type $\left.\begin{matrix}H^2O\\ H^3N\end{matrix}\right\}$, that is, as glycolamic, lactamic, oxybenzamic, oxytoluamic, &c. acids; (*e.g.* glycocol†, $C^2H^5NO^2 = \left(\begin{array}{l}\ H\qquad\ \}O\\ (C^2H^2O)''\\ \ H^2\qquad\ \}N\end{array}\right)$. Hippuric and toluyluric† acids then become respectively

$$\begin{array}{l}\quad H\qquad\ \Big\}O\\ (C^2H^2O)''\\ \ C^7H^5O\\ \quad H\end{array}\Bigg\}N\quad\text{and}\quad\begin{array}{l}\quad H\qquad\ \Big\}O\\ (C^2H^2O)''\\ \ C^8H^7O\\ \quad H\end{array}\Bigg\}N.$$

Formula 6 (derived from 5 by the addition of an atom of oxygen) represents triatomic acids containing O^3, and their derivatives. The number of substances which are certainly referable to this class is as yet very small; glyceric‡ acid, $C^3H^6O^4$ ($n=3, x=0$), and its homologue, $C^2H^4O^4$ ($n=2, x=0$), formed by the action of oxide of silver on a solution of bibromacetic§ acid, are examples.

Formula 7 (derived from 4 by the substitution of O for H^2) represents monobasic acids containing O^3, and their derivatives; for instance, pyruvic acid, $C^3H^4O^3$ ($n=3, x=0$), pyromeconic acid, $C^5H^6O^3$ ($n=5, x=1$), pyromucic acid, $C^5H^4O^3$ ($n=5, x=2$).

Formula 8 (derived from 7 by the addition of an atom of oxygen) represents the important class of bibasic acids containing O^4. This class includes oxalic acid and its homologues and analogues. The most recently discovered acids belonging to this group are malonic|| acid, $C^3H^4O^4$ ($n=3, x=0$), lipic¶ acid, $C^5H^8O^4$ ($n=5, x=0$), anchoic** acid, $C^9H^{16}O^4$ (lepargic acid, Wirz) ($n=9, x=0$), and insolinic†† acid, $C^9H^8O^4$ ($n=9, x=4$). Fumaric acid, $C^4H^4O^4$ ($n=4, x=1$,), pyrocitric acid, $C^5H^6O^4$ ($n=5, x=1$), and camphoric acid, $C^{10}H^{16}O^4$ ($n=10, x=1$), also belong to this class.

Formulæ 9, 10, 11, 12. Substances which we can confidently refer to any

* Comp. Kekulé, Ann. Chem. Pharm. civ. 141, 149; cvi. 150.
† Kraut, Ann. Chem. Pharm. xcviii. 360.
‡ Debus, Ann. Chem. Pharm. cvi. 79; Socoloff, ibid. 95.
§ Perkin and Duppa, Chem. Soc. Quart. Journ. xii. 6.
|| Dessaignes, Ann. Chem. Pharm. cvii. 251.
¶ Wirz, ibid. civ. 278. ** Buckton, Chem. Soc. Quart. Journ. x. 166.
†† Hofmann, ibid. ix. 210; Ann. Chem. Pharm. xcvii. 197.

of these formulæ are rare. Tartronic acid, $C^3 H^4 O^5$ ($n=3, x=0$), illustrates formula 9; orsellic acid, $C^8 H^8 O^4$ ($n=8, x=2$), formula 10; mesoxalic acid, $C^3 H^2 O^5$ ($n=3, x=0$), formula 11; and aconitic acid, $C^6 H^6 O^6$ ($n=6, x=1$) and chelidonic acid, $C^7 H^4 O^6$ ($n=7, x=3$), formula 12.

By comparing these twelve formulæ, it will be seen that 2 and 3 differ from 1 by containing respectively one and two atoms more oxygen, and that the same relation also exists among 4, 5, and 6; among 7, 8, and 9; and among 10, 11, and 12; and further, that 4, 7, and 11 respectively differ from 1 by the substitution of O for H^2, of O^2 for H^4, and of O^3 for H^6, and that the same relations are repeated among 2, 5, 8 and 11, and among 3, 6, 9 and 12. That is, the substances represented by the formulæ in the second, third, and fourth columns are oxygen substitution-products of the substances represented by the formulæ in the first column, and of these latter substances, the second and third are formed from the first by direct oxidation. Hence all the twelve members of the group are genetically connected with the first member. Comparing the chemical function of each with its composition and corresponding place in the group, we see that the formulæ in the top line represent monatomic compounds, those in the second line diatomic compounds, and those in the third line triatomic compounds. Formula 1 represents monatomic alcohols, and 4, 7, and 10 monobasic acids; formula 2 represents diatomic alcohols, and 5, 8, and 11, diatomic* or bibasic acids; formula 3 represents triatomic alcohols, and 6, 9, and 12 triatomic or terbasic acids.

From these considerations it will easily be seen how such a group might be extended so as to include tetratomic compounds, or substances in which more than six atoms hydrogen are replaced by oxygen. Such substances are hitherto so rare, that it does not seem worth while to complicate the general scheme of a chemical group by including their formulæ. Instances of both classes of compounds are, however, already known. Of the former class (tetratomic compounds), the following substances (which arrange themselves around an imaginary tetratomic alcohol, $C H^4 O^4$ ($n=1, x=0$), containing the radicle $(C)^{iv}$), are examples:—bichloride of carbon, $C Cl^4$, and Hofmann's cyantriphenyldiamine†, $C^{19} H^{17} N^3 = \left.\begin{matrix}(C^6 H^5)^3 \\ H^2 \\ (C)^{iv}\end{matrix}\right\} N^3$, obtained by its action on phenylamine; also, in a certain sense, all cyanogen compounds, and therefore such substances as melaniline, $C^{13} H^{13} N^3 = \left.\begin{matrix}(C^6 H^5)^2 \\ H^3 \\ (C)^{iv}\end{matrix}\right\} N^3$. Debus's glycosine‡, $C^6 H^6 N^4 = \left.\begin{matrix}(C^2 H^2)^{iv} \\ (C^2 H^2)^{iv} \\ (C^2 H^2)^{iv}\end{matrix}\right\} N^4$, may be regarded as a tertiary tetramine derived from another unknown tetratomic alcohol, $C^2 H^6 O^4$ ($n=2, n=0$), homologous with the foregoing. Several saccharine substances, for instance,

* Acids may be *diatomic*, or even *triatomic*, while in a strict sense they are *monobasic*. The acids of the glycolic series illustrate this distinction. These acids are monobasic; for they contain only one atom of hydrogen which is replaceable by metals; but at the same time they are diatomic, for they form acid amides (glycocol, &c.), chlorides containing Cl^2, and intermediate chlorohydrates containing 1 atom chlorine. As Kekulé has pointed out (Lehrbuch d. organ. Chemie, 1859, p. 130), they are precisely intermediate in respect of basicity (as well as of composition) between the glycols and the acids of the oxalic series. Thus, glycol easily exchanges two atoms of hydrogen for acid-radicles, glycolic acid exchanges one atom of hydrogen for acid-radicles (formation of benzoglycolic acid) and one atom for metals, while oxalic acid exchanges two atoms of hydrogen for metals, but none at all for acid-radicles.

† Hofmann, Proc. Roy. Soc. ix. 284.

‡ Debus, ibid. 297.

glucose and mannitane, have been shown by Berthelot* to have the function of polyatomic alcohols, and are probably more than triatomic. Of the latter class, meconic acid, $C^7 H^4 O^7$, is an example: it may be regarded as deriving from an unknown triatomic alcohol, $C^7 H^{12} O^3$ ($n=7, x=2$), by the substitution of O^4 for H^8.

Comparing together the corresponding compounds of different groups, chemists have long been accustomed to arrange them in *homologous*† series, or series in which there is a common difference between any two neighbouring terms of CH^2. The discoveries of late years make it appear probable that series of similar compounds also exist in which the common difference is H^2. Such series have been called *isologous*‡. The following pairs of compounds are isologous with each other:—tritylic alcohol, $C^3 H^8 O$, and allylic alcohol, $C^3 H^6 O$; propionic acid, $C^3 H^6 O^2$, and acrylic acid, $C^3 H^4 O^2$; valeric acid, $C^5 H^{10} O^2$, and angelic acid, $C^5 H^8 O^2$; caproic acid, $C^6 H^{12} O^2$, and sorbic acid, $C^6 H^8 O^2$ (difference$=2H^2$); sebacic acid, $C^{10} H^{18} O^4$, and camphoric acid, $C^{10} H^{16} O^4$.

If we confine ourselves to the comparison of bodies of the same chemical function, we can seldom find more than two or three which belong to the same isologous series; but if we compare together entire groups, we perceive the existence of considerable numbers of groups isologous with each other. It would be easy to render this evident by constructing a Table in which the various groups corresponding to differences in the values of n and x should be arranged so as to show at a glance their mutual relations of homology and isology; the groups corresponding to variations in the value of n, while that of x remains constant (*homologous groups*), being arranged in the same vertical column; and those which correspond to the same value of n, but to various values of x (*isologous groups*), in the same horizontal line, or *vice versâ*.

Gerhardt, in his 'Traité de Chimie Organique,' arranges all the chemical groups, which he includes in his scheme of classification, about two primary homologous series,—the acetic series and the benzoic series. In Kekulé's 'Lehrbuch der organischen Chemie,' an arrangement is adopted which is intermediate between that of Gerhardt and the classification in homologous and isologous series described above. Kekulé takes as the basis of his arrangement, the three primary series of homologous hydrocarbons, of which the first terms are—

Series I.	$C^2 H^4$ Ethylene.	$C^3 H^6$ Propylene.	$C^4 H^8$ Butylene.	$C^5 H^{10}$ Amylene.
Series II.		$C^6 H^6$ Benzole.	$C^7 H^8$ Toluole.	$C^8 H^{10}$ Xylole.
Series III.			$C^{10} H^8$ Naphtaline.	

It will be seen that there is a common difference of $C^4 H^2$ between the first terms of each of these series, and that, between the terms of the three series

* Ann. Chim. Phys. [3] xlvii. 297; Jahresber. viii. 678.

† Schiel, Ann. Chem. Pharm. xliii. 107 (1842), first pointed out the existence of substances possessing similar properties and differing in composition by $C H^2$, or a multiple thereof. This relation was afterwards shown by Gerhardt, Précis de Chimie Organique, (1844–45), to be of very frequent occurrence, and was distinguished by him by the name '*Homology*.'

‡ The word '*isology*' is used by Gerhardt (Traité, i. 127) in a somewhat less restricted sense. Gerhardt calls substances isologous which have the same chemical function, but which do not present the relation of homology; *e. g.* acetic acid, $C^2 H^4 O^2$, and benzoic acid, $C^7 H^6 O^2$.

which contain the same quantity of hydrogen, there is a common difference of C^3.

It can only be decided by the progress of discovery which of these modes of classifying chemical groups is the most accurate expression of their mutual relations.

If from the point of view which we have now reached, we look back at Gerhardt's system of types of decomposition, we see that almost all the advances which have been made in theoretical chemistry, since that system was proposed, are included in the development and systematizing of the idea of polyatomic radicles, an idea, which was to some extent adopted by Gerhardt, but which it could easily be shown was not followed out by him with perfect consistency.

In conclusion of our account of the recent advances of organic chemistry, we may enumerate some of the most important reactions, or methods of transformation, which, within the last four or five years, have been shown to be applicable to the compounds of various groups, or which, from their nature, appear to be capable of such a general application. They may be divided for this purpose into—

(I.) *Heterologous transformations*, or transformations in which there is a change of chemical functions, but in which the new substances produced belong to the same chemical group as the substances from which they are formed. (II.) *Homologous transformations*, or transformations in which there is a passage from one group to another homologous with it. (III.) *Isologous transformations*, or the passage from one group to another which is isologous with it.

I. *Heterologous transformations.* Several transformations of this kind have been already referred to as enabling us to pass from monatomic to polyatomic compounds, and *vice versâ*. We may mention further—

(A) The conversion of ethylene and its homologues into the corresponding monatomic alcohols by combining them with acids, and the subsequent decomposition by water, or by alkaline hydrates, of the compounds thus formed*; *e. g.*—

$$\underset{\text{Ethylene.}}{C^2H^4+H^2SO^4} = \underset{\text{Ethylsulphuric acid.}}{C^2H^6SO^4}$$

$$\underset{\text{Propylene.}}{C^3H^6+HCl} = \underset{\text{Chloride of trityl.}}{C^3H^7Cl}$$

(B) The formation of nitrogen compounds containing zinc (as zinc-amide, nitride of zinc, phenyl-zinc-amide, &c.) by the action of zinc-ethyl on the derivatives of ammonia†; *e. g.*—

$$\underset{\text{Zinc-ethyl.}}{C^2H^5Zn}+\underset{\text{Phenylamine.}}{C^6H^7N} = \underset{\text{Hydride of ethyl.}}{C^2H^6}+\underset{\text{Phenyl-zinc-amide.}}{C^6H^6ZnN}$$

(C) The substitution of ethyl and methyl for chlorine in combination with phosphorus and arsenic by the action of zinc-ethyl or zinc-methyl on terchloride of phosphorus or of arsenic‡; *e. g.*—

$$\underset{\text{Zinc-ethyl.}}{3C^2H^5Zn}+Cl^3P = 3Cl^2Zn+\underset{\text{Terethyl-phosphine.}}{(C^2H^5)^3P.}$$

(D) The similar substitution of ethyl and methyl for chlorine or iodine

* Berthelot, Ann. Chim. Phys. [3] xliii. 385; li. 81.

† Frankland, Proc. Roy. Soc. viii. 502.

‡ Hofmann and Cahours, Chem. Soc. Quart. Journ. xi. 56; Ann. Chem. Pharm. civ. 1; Ann. Chim. Phys. [3] li. 5.

in combination with mercury, lead, &c., or with the so-called organo-metallic compounds*; *e. g.*—

$$\underset{\text{Zinc-ethyl.}}{C^2H^5Zn} + ClHg = \underset{\text{Mercury-ethyl.}}{C^2H^5Hg} + ClZn.$$

$$\underset{\text{Zinc-ethyl.}}{C^2H^5Zn} + \underset{\substack{\text{Iodide of}\\\text{mercurous ethyl.}}}{C^2H^5Hg^2I} = \underset{\text{Mercury-ethyl.}}{(C^2H^5)^2Hg^2} + ZnI$$

$$\underset{\substack{\text{Zinc-}\\\text{methyl.}}}{CH^3Zn} + \underset{\substack{\text{Iodide of}\\\text{stanethyl.}}}{C^2H^5SnI} = \underset{\substack{\text{Stanethyl-}\\\text{methyl.}}}{\left.\begin{matrix}CH^3\\C^2H^5\end{matrix}\right\}Sn} + ZnI$$

(E) The substitution of potassium and sodium for zinc in combination with methyl or ethyl†:—

$$\underset{\text{Zinc-ethyl.}}{2(C^2H^5Zn)} + Na^2 = \underset{\text{Sodium-ethyl.}}{2(C^2H^5Na)} + Zn^2$$

(F) The formation of binoxides of organic radicles‡; *e. g.*—

$$\underset{\text{Chloride of benzoyl.}}{2(C^7H^5OCl)} + Ba^2O^2 = \underset{\text{Binoxide of benzoyl.}}{(C^7H^5O)^2O^2} + 2BaCl$$

(G) The conversion of aldehydes into the corresponding alcohols and acids by the action of alcoholic potash§; *e. g.*—

$$\underset{\substack{\text{Benzoic}\\\text{aldehyde.}}}{2C^7H^6O} + KHO = \underset{\substack{\text{Benzylic}\\\text{alcohol.}}}{C^7H^8O} + \underset{\substack{\text{Benzoate of}\\\text{potassium.}}}{C^7H^5KO^2}$$

$$\underset{\text{Camphor.}}{2C^{10}H^{16}O} + KHO = \underset{\substack{\text{Campholic}\\\text{alcohol.}}}{C^{10}H^{18}O} + \underset{\substack{\text{Camphate of}\\\text{potassium.}}}{C^{10}H^{15}KO^2}$$

(H) The formation of acediamine by the action of heat on hydrochlorate of acetamide‖:—

$$\underset{\text{Acetamide.}}{\left.\begin{matrix}H\\(C^2H^3)'''\end{matrix}\right\}N \atop \left.H\right\}O} + \underset{\text{Acetamide.}}{\left.\begin{matrix}H\\(C^2H^3)'''\end{matrix}\right\}N \atop \left.H\right\}O} = \underset{\text{Acediamine.}}{\left.\begin{matrix}(C^2H^3)'''\\H^3\end{matrix}\right\}N^2} + \underset{\text{Acetic acid.}}{\left.\begin{matrix}(C^2H^3)'''\\H\end{matrix}\right\}O^2}.$$

This reaction is interesting, as illustrating simultaneously the connexion of acetamide with the derivatives of ammonia and with the derivatives of water. Of the two atoms of acetamide which take part in the formation of acediamine, one reacts as an amide, the other as a hydrate. The following is a comparable reaction:—

$$\underset{\substack{\text{Chlorohydrated}\\\text{sulphuric acid.}}}{\left.\begin{matrix}Cl\\(SO^2)''\end{matrix}\right\} \atop \left.H\right\}O} + \underset{\substack{\text{Chlorohydrated}\\\text{sulphuric acid.}}}{\left.\begin{matrix}Cl\\(SO^2)''\end{matrix}\right\} \atop \left.H\right\}O} = \underset{\substack{\text{Chlorosul-}\\\text{phuric acid.}}}{(SO^2)''Cl^2} + \underset{\substack{\text{Sulphuric}\\\text{acid.}}}{\left.\begin{matrix}(SO^2)''\\H^2\end{matrix}\right\}O^2}.$$

(I) The action of chloride of phosphorus on amides, and the formation thereby of a new class of chloronitrides¶; *e. g.*—

* Buckton, Proc. Roy. Soc. ix. 309; Frankland, Proc. Roy. Soc. ix. 672.
† Wanklyn, Ann. Chem. Pharm. cviii. 67.
‡ Brodie, Proc. Roy. Soc. ix. 361; Ann. Chem. Pharm. cviii. 325.
§ Cannizzaro, Ann. Chem. Pharm. lxxxviii. 129; Kraut, ibid. xcii. 66; Berthelot, Ann. Chim. Phys. [3] lvi. 79.
‖ Strecker, Ann. Chem. Pharm. ciii. 325.
¶ Gerhardt, Ann. Chim. Phys. [3] xlvi. 172; liii. 302; Limpricht and V. Uslar, Ann. Chem. Pharm. cvi. 32, 41.

$$\left.\begin{array}{l}\left.\begin{array}{c}H\\(C^7H^5)'''\end{array}\right\}O\\\quad H\end{array}\right\}N + PCl^5 = \left.\begin{array}{l}\left.\begin{array}{c}Cl\\(C^7H^5)'''\end{array}\right\}\\\quad H\end{array}\right\}N + H\,Cl + PO\,Cl^3.$$

Benzamide. Chloride of benzamidyl (Gerh.).

$$C^7H^8N^2SO^3 + PCl^5 = C^7H^7N^2SO^2Cl + HCl + POCl^3$$

Sulphobenzamide. Chloride of sulphobenzamidyl.

(Sulphobenzamide may be derived from the quadruple type $\left.\begin{array}{c}H^2\\H^2O\\2(H^3N)\end{array}\right\}$ by the substitution of the tetratomic radicle $(C^7H^4)^{iv}$ for H^4 and the biatomic radicle $(SO^2)''$ for H^2; its formula then becomes $N\left\{\begin{array}{l}\left\{\begin{array}{c}H\ H\\(C^7H^4)^{iv}\end{array}\right\}O\\(S\ O^2)''\\H\ H\end{array}\right\}N$. The action of chloride of phosphorus upon it is to replace the H^2O of the type by HCl; the product of this action may be written

$$N\left\{\begin{array}{l}\left\{\begin{array}{c}H\ Cl\\(C^7H^4)^{iv}\end{array}\right\}\\(S\ O^2)''\\H\ H\end{array}\right\}N, \text{ type } N\left\{\begin{array}{l}\left\{\begin{array}{c}H\,Cl\\H\,H\end{array}\right\}\\H\,H\\H\,H\\H\,H\end{array}\right\}N.)$$

(K) The formation of aldehydes from their corresponding acids by distilling their alkaline salts mixed with an alkaline formate*; *e.g.*—

$$C^7H^5KO^2 + CHKO^2 = C^7H^6O + CK^2O^3$$

Benzoate of potassium. Formate of potassium. Benzoic aldehyde. Carbonate of potassium.

(L) The substitution of hydrogen for compound radicles contained in organic bases†; *e.g.*—

$$\left.\begin{array}{c}C^6H^5\\C^2H^5\\C^2H^5\end{array}\right\}N + H^2O = \left.\begin{array}{c}H\\C^2H^5\\C^2H^5\end{array}\right\}N + C^6H^6O$$

Diethylphenylamine. Diethylamine. Phenylic alcohol.

$$\left.\begin{array}{c}H\\C^2H^5\\C^2H^5\end{array}\right\}N + H^2O = \left.\begin{array}{c}H\\H\\C^2H^5\end{array}\right\} + C^2H^6O$$

Diethylamine. Ethylamine. Alcohol.

$$\left.\begin{array}{c}H\\H\\C^2H^5\end{array}\right\}N + H^2O = \left.\begin{array}{c}H\\H\\H\end{array}\right\}N + C^2H^6O$$

Ethylamine. Alcohol.

II. *Homologous transformations.*

(A) The combination of carbonic anhydride with the compounds of the alcohol radicles with alkali-metals‡; *e.g.*—

* Piria, Ann. Chim. Phys. [3] xlviii. 113; Ann. Chem. Pharm. c. 104; Limpricht, Ann. Chem. Pharm. xcvii. 368; Ann. Chim. Phys. [3] xlviii. 118.

† Matthiessen, Proc. Roy. Soc. ix. 118, 635.

‡ Wanklyn, Ann. Chem. Pharm. cvii. 125; cxi. 234; Ann. Chim. Phys. [3] liii. 42. The above reaction corresponds closely with that of sulphurous anhydride on zinc-methyl:—

$$CH^3Zn + SO^2 = CH^3ZnSO^2.$$

Zinc-methyl. Methylodithionate of zinc.

Hobson, Chem. Soc. Quart. Journ. x. 243; Ann. Chem. Pharm. cvi. 287.

$$CH^3 Na + CO^2 = C^2 H^3 NaO^2$$
Sodium-methyl. Acetate of sodium.

(B) The supposed formation of methyl compounds from acetone*; *e.g.*—

$$C^3 H^6 O + O = C^3 H^6 O^2$$
Acetone. Acetate of methyl.

(C) The formation of complex hydrocarbons (ethylene, propylene, amylene, benzine, naphtaline, &c., by the action of heat on organic substances of simpler constitution. Synthesis of organic compounds)†.

III. *Isologous transformations.*

(A) The conversion of glycerine into iodopropylene, and of the latter into allylic alcohol ‡:—

$$2(C^3 H^5 I) + Ag^2 C^2 O^4 = 2Ag I + (C^3 H^5)^2 C^2 O^4$$
Iodopropylene. Oxalate of silver. Oxalate of allyl.

$$(C^3 H^5)^2 C^2 O^4 + 2N H^3 = 2C^3 H^6 O + C^2 H^4 N^2 O^2$$
Oxalate of allyl. Allylic alcohol. Oxamide.

(B) The production of cinnamic aldehyde from acetic and benzoic aldehydes §:—

$$C^2 H^4 O + C^7 H^6 O = C^9 H^8 O + H^2 O$$
Acetic aldehyde. Benzoic aldehyde. Cinnamic aldehyde.

(C) The production of cinnamic acid from chloride of acetyl and benzoic aldehyde ‖:—

$$C^2 H^3 O Cl + C^7 H^6 O = C^9 H^8 O^2 + HCl.$$
Chloracetyl. Benzoic aldehyde. Cinnamic acid.

Throughout the foregoing Report Gerhardt's atomic weights have been used without discussion; for it seemed superfluous to enumerate once more the reasons for adopting them, which, as the science advances, become more and more numerous and conclusive ¶. It may, however, be expected that some notice should be taken of such objections as have been recently made against this system.

Within the last few years three different chemists have, for very different reasons, proposed to modify Gerhardt's atomic weights, but they all agree in adopting the doubled atomic weight of carbon, while they reject the doubled

* Friedel, Ann. Chem. Pharm. cvii. 174; cviii. 388.

† Berthelot, Ann. Chim. Phys. [3] liii. 69.

‡ Hofmann and Cahours, Chem. Soc. Quart. Journ. x. 316; Ann. Chem. Pharm. cii. 285; Ann. Chim. Phys. [3] l. 432.

§ Chiozza, Ann. Chem. Pharm. xcvii. 350.

‖ Bertagnini, Ann. Chim. Phys. [3] xlix. 376.

¶ Some recent experiments nevertheless tend to show that the atomic weights assigned by Gerhardt to some of the metals ought to be doubled. For instance, the vapour-density of zinc-ethyl (Frankland, Ann. Chem. Pharm. xcv.), the way in which zinc combines with iodide of ethyl (similar to the combination of oxygen with zinc-ethyl, $Zn^2 + C^2 H^5 I = C^2 H^5 Zn^2 I$, and $O + C^2 H^5 Zn = C^2 H^5 O Zn$), the vapour-density of mercury-methyl and of mercury-ethyl (Buckton, Proc. Roy. Soc. ix. 92, 311), and the combination of mercury with iodide of ethyl (forming $C^2 H^5 Hg^2 I$), seem to show that the atomic weights of zinc and mercury are twice as great as they were adopted by Gerhardt. Similar reasons may be urged in favour of doubling the atomic weight of tin, as recommended some time since by Odling (Phil. Mag. [4] xiii. 434). As these points, however, belong to inorganic chemistry, we cannot do more than simply refer to them here.

atomic weight of oxygen: we refer to Limpricht*, Kolbe†, and Couper‡. The first of these chemists founds his objection to the greater atomic weight of oxygen upon the fact that some salts crystallize with a quantity of water containing an odd multiple of 8 parts of oxygen. To this it may be answered, that the function of water in crystallized salts is not sufficiently well understood to warrant our drawing conclusions of any importance from the quantity of it contained in any particular substance, and that no reason has yet been shown why several atoms of a salt should not crystallize with one atom of water, as well as several atoms of water with one atom of a salt.

The objections of Kolbe are founded on more general considerations. By comparing the composition of the so-called organo-metallic bodies with that of the inorganic compounds of the metals which they contain, he came to the conclusion that the metallic oxides are typical of the compounds of the metals with organic radicles.

For instance, taking the atomic weight of oxygen at 8, and writing oxide of zinc and arsenious anhydride ZnO and AsO^3 respectively, we get the following comparison of formulæ:—

Oxide of zinc ZnO	Arsenious anhydride AsO^3
Zinc-ethyl .. $ZnEt = ZnC^2H^5$	Oxide of arsenomonomethyl ...... $AsO^2Me = AsO^2CH^3$
	Oxide of kakodyl .. $AsO\,Me^2 = AsOC^2H^6$
	Termethylarsine .. $AsMe^3 = AsC^3H^9$.

Admitting the accuracy of such formulæ, it was natural to extend similar views to those compounds of carbon which do not contain metals. Accordingly, Kolbe regards carbonic anhydride CO^4, the highest known oxide of carbon, as the type of a large number of other carbon-compounds. According to him, the replacement of 1 atom oxygen in carbonic anhydride by 1 atom hydrogen, or 1 atom of an alcohol-radicle, gives monobasic acids, such as those of the acetic and benzoic series; the like replacement of 2 atoms oxygen gives aldehydes and acetones; the replacement of 3 atoms oxygen gives ethers; and lastly, the replacement of all the oxygen gives alcohol-radicles and their hydrides. The following illustrations will make this clearer:—

$$\text{Type ..}\ C\left\{\begin{array}{l}O\\O\\O\\O\end{array}\right.$$

I.		II.		III.		IV.	
$C\left\{\begin{array}{l}H\\O\\O\\O\end{array}\right.$	$C\left\{\begin{array}{l}CH^3\\O\\O\\O\end{array}\right.$	$C\left\{\begin{array}{l}H\\CH^3\\O\\O\end{array}\right.$	$C\left\{\begin{array}{l}CH^3\\CH^3\\O\\O\end{array}\right.$	$C\left\{\begin{array}{l}H\\H\\H\\O\end{array}\right.$	$C\left\{\begin{array}{l}H\\H\\CH^3\\O\end{array}\right.$	$C\left\{\begin{array}{l}H\\H\\H\\H\end{array}\right.$	$C\left\{\begin{array}{l}H\\H\\H\\CH^3\end{array}\right.$
Formic acid (anhydrous).	Acetic acid (anhydrous).	Aldehyde.	Acetone.	Methylic ether.	Ether.	Hydride of methyl.	Methyl.

It must certainly be considered fortunate for the interests of science that Professor Kolbe should himself have extended his theory to the purely organic compounds of carbon; for these being the precise substances of

* Limpricht, Grundriss der organischen Chemie (1855).

† Ann. Chem. Pharm. ci. 257. The same views were also advocated by Frankland in a lecture delivered at the Royal Institution, May 28th, 1858. (See Journ. Roy. Instit.)

‡ Ann. Chim. Phys. [3] liii. 469; Ann. Chem. Pharm. cx. 46.

which our knowledge is the most complete, the application of the theory to them makes it possible to arrive at a more certain conclusion as to its value, than would be the case were it confined to the substances to which it was originally applied. Respecting the above and similar formulæ, it may be observed,—

1. That, leaving out of view the substances under discussion, there is no reason to believe that the oxygen in carbonic-anhydride can be divided into more than two parts; there is no evidence that carbonic anhydride contains more than two atoms of oxygen.

2. That there is no similarity, nor definite gradational difference of properties, between the type $C O^4$ and the substances represented as deriving from it.

3. Two out of the four formulæ given above, namely the first and third, are in direct opposition to Gerhardt's atomic weights; we know, however, that they represent only half an atom of the bodies to which they are assigned.

Views respecting the nature of chemical affinity have induced Couper to adopt 8 as the atomic weight of oxygen. He, however, finds that, owing to a peculiar tendency which oxygen possesses to combine with oxygen, the smallest quantity of it which ever enters into combination is twice 8. This being admitted, it seems a matter of minor importance whether the smallest combining proportion of oxygen should be represented by the symbol $O=16$, or by the symbol $O^2=16$.

September 10, 1859.

Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester. By JAMES BUCKMAN, *F.S.A., F.L.S., F.G.S., &c., Professor of Natural History, Royal Agricultural College.*

THE following notes are upon experiments which have been completed or are still in progress in the experimental garden of the Royal Agricultural College, and this Report is furnished at the instance of the Natural History Section, the experiments having been made the subject of a grant from the funds of the British Association.

It is hoped that the present Report will show the desirability of continuing experiments upon plants, as whatever effect they may have upon our theoretical views, I think it will clearly be seen that many practical matters of great importance are involved in inquiries of this kind, and I shall therefore not detain the Section with any lengthened introduction, but at once ask for a kind and considerate attention to the following notes:—

The cultivation of flax or lintseed offers such interesting matter to the naturalist, as being of importance in an economic and agricultural point of view, that we cannot help detailing some experiments connected therewith.

Plot A was sown in drills with a pure sample of linseed grown on the farm of the Royal Agricultural College.

Plot B was sown with a like weight of seed uncleaned, it therefore consisted of full half its weight of weed-seeds.

Plot C was sown with a like weight of pure seed as in plot A, to which was afterwards added a good sprinkling of dodder-seed, viz. *Cuscuta epilinum.*

These beds were left unmolested, not even being weeded. The seed became ripe in the middle of August, at which time the following observations were noted upon each of them:—

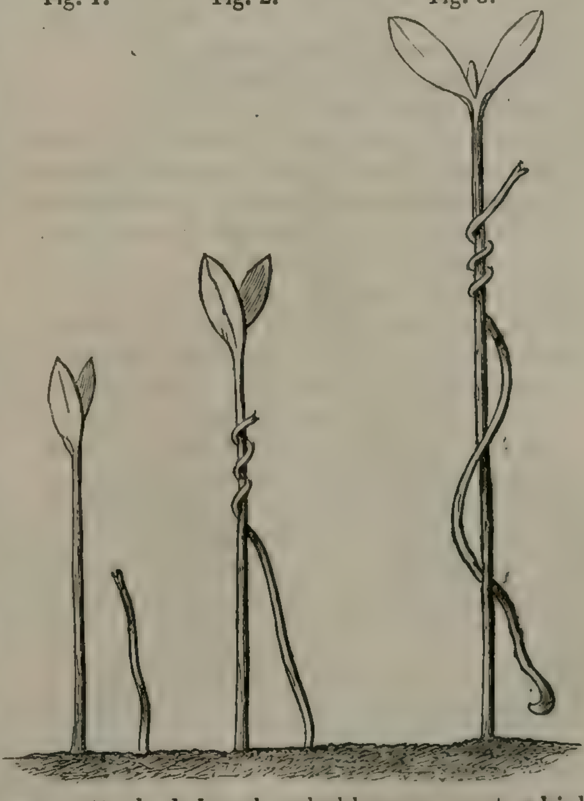
	Average height in inches.	Proportionals of fibre.	Proportionals of seed.
Plot A. Regular in the rows, and clear of weeds . .	36	50	50
Plot B. Irregular, flax sparse, weeds plentiful	34	20	25
Plot C. Borne down to the ground with dodder, and most of the flax stems rotting	32	15	20

Hence, then, in as far as the economics of the question are concerned, we may safely conclude that the sowing of dirty flax-seed at any price is disadvantageous, and this not only that the resulting crop, if not quite ruined, is certain to be diminished in quantity and injured in quality, but, as ill weeds grow apace, all the sorts growing with the flax had sown much of their seeds before the flax-seed itself had ripened, so that a succession of weeds is by this means entailed upon the farm from generation to generation.

As regards the plot with dodder, the object of sowing these together was for the purpose of observing with my Class the manner in which the parasite became attached to its foster-parent, and I therefore offer the following remarks upon the growth of the *Cuscuta epilinum*, not as containing any new results, but as offering an example of the kind of experiments followed out in my botanical garden.

In about four days after the seed of the dodder was sown, a few whitish thread-like germs of about three lines in length were seen protruding from the soil, some of these being quite free, others crowned with the seed testa. Three days afterwards the flax came up, and the dodder might then have been seen, as in the accompanying fig. 1, bending its germ towards a flax-plant; by this time it has doubled in length; and if the flax-plant be far away, it seems to be endowed with the power of growing to as much as an inch in length in order to reach it, whilst in experiments of dodder seed sown by itself, the germs were always short and soon withered; but on inserting other plants in the same pot, they became attached to them, as *Radish*, *Tomato*, *Groundsel*, and *Chickweed* were all in this way attacked by the dodder amongst which young plants were inserted; and in one case, where a pot of growing flax dodder was placed near a Sedum in my conservatory, the latter was attacked, and the dodder grew upon it most vigorously.

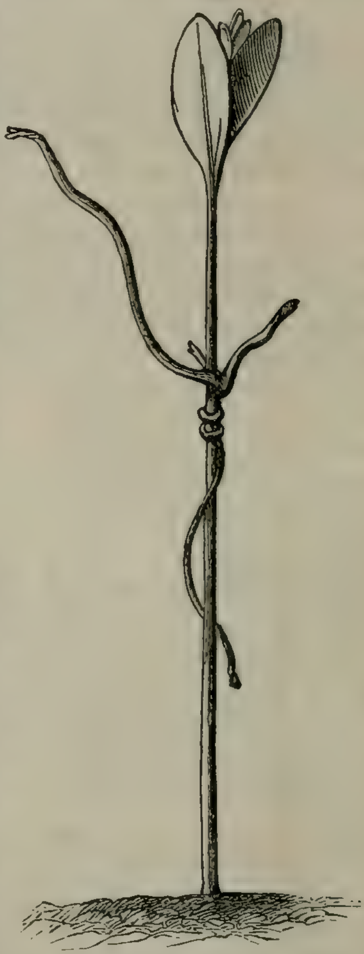
Fig. 1. Fig. 2. Fig. 3.



In a short time after the germination of the dodder and the flax, the former reaches the latter, when it makes one or two coils round the flax stem, as shown in fig. 2, when immediately small cells begin to develope themselves inside the dodder coils; these form aërial roots which soon penetrate the flax, which is now growing in size and height. It is now incorporated with the circulation of the foster-parent; its own radicle is no longer required in connexion with the soil, and so the whole dodder plant is elevated by the flax, as shown in fig. 3.

When this attachment is completed it pushes forth new fibres, each of which behaves like the parent germinal fibre and attacks any plant growing near, so that we need not wonder at clusters of dodder rapidly advancing in the flax crop where it is sown. Our fig. 4 represents the advance in growth of a single dodder plant ve days after its attachment.

Fig. 4.



Plot D.—This is *Linum perenne*, before reported upon; it still keeps up its character, and is a fine upright perennial flax bearing one large and a second smaller crop of stems annually; however, from thus overgrowing, the plants are gradually wearing out.

Plot E is from the seed of the above; it has the same appearance, but is not yet so vigorous and tall in growth. Seed is sowed from this to carry on experiments.

Plot F. *Rosa spinosissima* (L.).

Plot G. *Rosa Doniana* (Woods).

I procured specimens of these two forms of Rose from the neighbourhood of Worcester, in December 1857, having been taken to their localities by my friend Mr. Edwin Lees. The habitats of both these are much alike, being on the margins of the old Severn Straits, and they serve to mark the former marine conditions which pertained until comparatively lately along the course of the Severn into the Midland Counties.

Several specimens were forwarded to my gardener and planted in a prepared border, and at the present moment they present such a uniformity of appearance and habit, with their small leaves and abundant long straight and small spines, with a creeping rhizomatous habit of growth, that convinces me they are not specifically distinct; but the latter is probably a variety of *R. spinosissima.* Hooker, however, has placed it as a var. of *R. Sabini*, in which he is followed by Babington; whilst Bentham has favoured the notion that the true place of *R. Doniana* is with the *Rosa villosa*, an arrangement, if admitted, which will go far in my opinion to reduce most of the species (of authors) of this genus which we have in England to the inferior rank of varieties, a conclusion which I have no doubt would be justified to a much greater extent than even the "lumping" botanist is prepared for with careful growth from seed, and we are hence collecting rose seeds for experiment, in which we ask the aid of botanists for the rose forms of their localities.

Plot H. *Viola odorata.*—All the roots in this plot turned out this year to be the lilac variety of *V. odorata*, much to the astonishment of my gardener who planted most of them for *V. hirta*; however, as these were not planted under my own superintendence, I cannot answer for the results, though I quite think that Mr. Bentham's remarks under the head of *V. hirta*, are not without foundation; they are as follows:—"Hairy Violet, *Viola hirta*, Linn. Very near the *sweet* violet, and most probably a mere variety." This seems confirmed by the immense varieties on the Great Oolites and the Forest Marble clays of this district, presented by both *odorata* and *hirta*. These then are reserved as subjects for future experiment, to which end a quantity of seeds are collected.

Plot I. *Myosotis*.—Some years since I was charmed with the appearance of a tuft of *Myosotis* which I saw at my nurseryman's, since which time I have always had some of it in cultivation as early spring flower. My specimens were allowed to seed on the ground, and the young plants are shifted about when required for garden decoration. Now it is remarkable that the original roots are *perfectly perennial*, but the seedlings at best are only sub-perennial. In most the seed comes up the same summer that it has been scattered, and flowers, seeds and dies the next spring, which indeed is precisely the habit of *Myosotis arvensis*; and hence I conclude that the original plants, if propagated by slips, the usual gardeners' method, would be the *M. sylvatica* of authors, the seedling the large-flowered form of *M. arvensis*. In other words, I think these experiments tend to show that these two supposed species are but varieties, an idea indeed which Sir W. Hooker seems to favour in the 5th edition of his 'British Flora.'

In as far as my experiments have progressed with these plants, I am induced to adopt Mr. Bentham's view, that the *M. alpestris* (Schmidt) is the larger flowered form of *M. sylvatica*; for as the old stock of our favourite seemed to be diminishing in the size and intensity of the colour of its flowers, I have this year introduced some *M. alpestris* from a friend's garden, and I fully expect the seedlings of this to take on the following declension:—

M. palustris? (perennial).
M. alpestris (perennial).
M. sylvatica (sub-perennial and annual).
M. arvensis, fl. maxima (annual).
M. arvensis, fl. minor (annual).

Of the three last of these descents I am perfectly clear, and Mr. Bentham, under the *Myosotis sylvatica*, has the following remarks:—"It varies much in size and stature; in lower shady situations, and in our gardens, the stems will attain a foot or more in length with rather small flowers. The alpine form, with larger flowers, is by some distinguished as a species under the name of *M. alpestris**."—Handbook, p. 377.

In this genus then we may expect to find some interesting results from experiments, as a further contribution to which end I hope to get seeds of the *M. palustris* for garden culture, some experiments of this kind in a garden I have left inclining me to think this water form as not so distinct from the terrestrial ones as some may think.

Plot J. *Datura Tatula*, Purple Thorn-Apple.—The crop of this season is from seed supplied by Butler of Covent Garden; it is at least twice the size of that which was previously reported upon, and the flowers and whole plant

* This view is also shared by Mr. Babington.

appear to be unusually dark in colour, in which it contrasts finely with the following.

Plot K. *Datura Stramonium*, American Thorn-Apple.—Only three plants have this year arrived at maturity, but its extreme whiteness is quite remarkable when placed beside the *D. Tatula*, a crop, which, it will be remembered, was formerly reported as being almost destitute of colour.

Plot L. *Dipsacus sylvestris* (L.) } mixed.
„ *fullonum* (L.) }

These, though distinguished by Linnæus and retained as species by Smith and Hooker, are *shown* by my garden experiments to be but varieties; indeed, Sir W. Hooker, in speaking of the reflexed scales, says, "These hooks become obsolete by long cultivation in poor soil, and there is reason to believe that *D. fullonum* is but a variety of *D. sylvestris*." In this he has been followed by other authors; as yet I am not aware of any direct observations upon the point, but my experiments upon the two forms enable me to supply this.

In 1857 I had a plot each of *Dipsacus sylvestris* and *D. fullonum* flowering, and at last ripening their seed side by side. This seed became scattered about the garden, and not having a distinct plot of teasels for botanical illustration, a plot was made of the most vigorous plants which could be selected from the self-sown examples without an attempt to discriminate the different sorts, which indeed would have been impossible at this stage of growth. Now the result at the time of my writing is very striking; there are the true *D. sylvestris* with the straight scales, the *D. fullonum* with the stiff reflexed hooks, and all intermediate stages, so that it is most difficult to separate them, if indeed they are to be distinguished. In order, therefore, to keep up the fulling apparatus of the teasel in perfection, it is important that the plants be cultivated, as, letting them go wild, they revert to the useless form; and strong land is also necessary to the growth of stiff hooks.

Plot M. *Carduus tuberosus*.—This plant, which I was fortunate enough to discover in North Wilts, about the Avebury Circles, is the same as was recorded some five-and-twenty years since, as existing at Great Ridge in the south of that county, It has for a long time been lost to our flora, though a few specimens were still in cultivation in the garden of my friend Mr. Cunnington of Devizes.

In August 1857 I brought home a few plants from Avebury, which made some new shoots last year, but did not flower; they, however, had the characteristic tubers of a good size. These were parted, and now occupy the plot as above.

As now seen in their wild habitat, the flower-stem is scarcely above a foot high, with from two to four flowers each. In cultivation it has attained the height of 3 feet, with a large mass of stems to each plant, bearing from six to twelve flower-heads each: the flowers are very showy, and, like the tubers, increase in size under cultivation. As this plant yields these tubers so abundantly, I boiled some of them to ascertain if they were edible; and as they are made up of feculent matter which proves to be tender and sweet to the taste, I am not quite sure that this thistle might not be cultivated as a vegetable to advantage.

Seeds of the plant have been saved for the purpose of experiment, as I have not yet given up the idea of the hybridity of the *Carduus tuberosus*; and, with all its large flowers, I may observe that it seeds only sparingly.

Plot N. *Carduus acaulis*.—By the side of the above are two varieties of this plant occupying the same plot; one the normal stemless form, another with stems as much as 2 feet high, each of which bears from four to eight heads of flowers. Mr. Bentham, in his 'Handbook of the British Flora,' has the following remark under the head of *Carduus acaulis* :—"In some situations on the continent, the stem will grow out to 6 or 8 inches; but this variety is very rare in England." It is, however, common on the Cotteswolds, with stems a few inches in length, and, as we have seen, this increases very much under cultivation.

Plots O and P. *Yellow Globe Mangel Wurzel.*—The question is often asked us by farmers and others, as to whether the leaves of this plant cannot be used for feeding purposes, and so be plucked off from time to time as the root is growing without prejudicing the amount of root-growth. Of these plots, then, one has had all the external leaves removed twice during the present season, and will be so served once more, the plot being left intact. Already there is an immense difference in the size of the roots, those on the stripped plot being at present not more than half the size of the others*.

In reference to this subject, I may refer to a like experiment which I carried out in my garden in 1854. Two plots of each of five sorts of mangel wurzel were sown side by side. Of these a plot of each was denuded of leaves in the manner just indicated, the rest being left uninjured, and the following Table will give the result:—

Table of Growth of Mangel Wurzel.

Sorts.	Proportionals.	
	Not stripped of outer leaves.	Stripped of outer leaves.
Red globe	31·0	23·5
Yellow globe	45·0	18·5
Long red	49·0	18·0
Long yellow	35·5	18·0
Long white	32·5	19·5
Total . .	193·0	97·5

Here then it will be seen that the poorer the crop the less the injury done to the leaves.

Plot Q. *Indian Rape.*—Some seed so called, obtained from a *seedsman*, was sown in April in drills, but not a single specimen germinated. I have, however, been more successful with a sample obtained from a seed-crusher, as four-fifths came up, and my samples are progressing towards maturity, although not yet sufficiently far advanced to enable me to determine the now important question of—What is Indian Rape? First, then, in order to bespeak attention to this matter, it will be well shortly to review its points of interest; of these the following extract from a trade circular will shortly explain one:—

"I have sold this day some India rape-seed for mixing with turnip-seed, and enclose a sample. If you will have some at 56*s*. per quarter in the docks, you can have it, if unsold, to your answer."

This, be it remembered, to *mix with* turnip-seed, which is sold at from 9*d*. to 1*s*. per lb., a quarter being probably as much as 500 lbs.—a good margin for profit!

Another phase of the subject will be found in the Report of the Trial of Greville *versus* Briggs, at the late Wells Assizes, in which damages were

* This experiment gave the following results:—

	lb. oz.
Plot O. Leaves removed, 21 plants weighed	24 4½
Plot P. Leaves intact, 20 plants weighed	61 5½

(October 27, 1859.)

sought and obtained for some cattle that were proved to have been poisoned by rape-cake, the defence being that the cake in question was made from Indian rape.

Now it would appear that very large quantities of this seed are sold annually, partly to the seedsman, but more to the seed-crusher; the former mixes it with turnip-seed to adulterate it,—carefully preparing it, however, to prevent germination, as in our turnip-drilling age, a false plant would be detected in the rows*.

The seed-crusher mixes it with true rape in crushing for rape-oil, and so the resulting cake appears to get poisonous properties in proportion to the quantity of "Indian rape" present, the truth being that this seed has all the properties of *Sinapis arvensis*—charlock mustard, which acts as an irritant poison to the cattle.

Now, although we are not quite certain as to the specific identity of our Indian rape plants, we incline to the notion that it is, if not true *Sinapis arvensis*, as we know it in this country, a variety of this plant; but upon this I shall be enabled to report more at length in another season.

Plot R. *Brassica oleracea*.—I this year gathered seeds of this wild cabbage from Llandudno, N. Wales, and I have some just germinated; upon these I hope to carry on a series of experiments for some years to come, with the object of tracing the production of the well-marked varieties which this plant is capable of producing.

Plot S. *Trigonella Fœnum-græcum*.—The Fenugreek, as a plant which is likely soon to occupy a great deal of attention, has formed a subject for experiment, the object being to ascertain if this eastern plant would perfect its seed in this country. My plot is now in full growth, and its abundance of long-pointed legumes, full of all but ripened seeds, are satisfactory as to the capabilities of the plant for cultivation in even exposed situations.

Fenugreek is now being extensively used as a flavouring ingredient for the so-called "Concentrated Cattle Foods;" and though the notion of food being concentrated by the addition of this plant is proved to be a fallacy, yet I think there can be little doubt that even inferior pulse or grain may be made more palatable by a flavouring principle; and it is a question of as great importance to the well-being of our domestic animals as to ourselves, whether nutrition is not increased by flavour.

The whole plant, but especially the seeds of the Fenugreek, contains a chemical principle which has been named "*Cumarin*," which is described as follows:—

"*Cumarin*, $C_{18}H_6O_4$, is found in Tonka Beans, in which it sometimes appears in the shape of crystals; in the flowers and whole plant of *Melilotus*; in *Asperula odorata* and *Anthoxanthum odoratum*, and probably in other aromatic plants."—Schlossberger's 'Organic Chemistry.'

Fenugreek is highly flavoured with cumarin; and as the presence of this in some grasses, especially in *Anthoxanthum odoratum*, is the cause of a good flavour to hay, and for which horses always smell so carefully before eating, there is every reason to believe that this principle is being extended to other cattle foods, and in consequence the use of Fenugreek is rapidly extending. Cattle-food manufacturers are starting up in every district, and with all of them this plant is employed as the flavouring ingredient; and it would appear at a great profit; as food, which before mixing would be about £7 per ton, is

* In reference to this I may say that in Wales drilling of turnips is almost unknown, so that preparation of false seed is not required, as these simply get looked upon as weeds "natural to the soil;" but I saw the other day a patch of Swedes which had been drilled, and I counted 96 *plants of Charlock, and* 4 *only*! *of Swedes* to each hundred in the rows.

increased to a charge of somewhere about £42 per ton. Now if the system of flavouring cattle food be found to answer and the principles just enunciated are found to be correct, there need only be an addition of a few shillings per ton as the cost of rendering cattle food more palatable and so easier of digestion, and consequently of a higher nutritive value.

I am informed that the seeds have recently doubled in price in consequence of their extended use; but the experiment has shown that we can, if required, grow it in this country.

Plots T, U, and V are occupied with vetches derived from the *Vicia angustifolia.*

T. *V. angustifolia,* var. *sativa.* Spring crop.
U. *V.* „ var. *sativa.* Winter crop.
V. *V.* „ formerly var. *sativa,* but being left wild as a permanent crop, is again reverting to its wild form.

The facility with which wild vetches can be cultivated into new forms and of exceeding rank growth is a matter fully settled by these experiments, and they take so short a time to bring about, that they can be easily repeated by any one.

Plot W. *Scorzonera.*

Plot X. *Salsafy.*

These were both drilled from old seed, and their paucity of plants offers good instruction in relation to this subject. In an agricultural point of view, nothing can be considered more objectionable than want of care in this respect. Though these are plants of the same family, there has been a great difference in the germination of their five-year old seed.

Of Scorzonera came up about 2 per cent.

Of Salsafy came up about 10 per cent.

The plants, however, look well and healthy.

These are amongst the good vegetables which the comparatively flavourless and innutritious potato has displaced.

Plot Y. *Dioscorea Batatas,* Potato Yam.—These plants have this year been elevated on high ridges, but do not grow vigorously in the exposed experimental garden. However, in my own private garden in the town, which is surrounded by high walls and well-sheltered, my crop promises to be better than usual, and I shall look forward to the produce with some interest.

Plot Z. *Tamus communis,* Black Bryony, as being an allied plant, is now the subject of experiment. This year's crop is from seed sown last summer; they are a little larger in the tuber than peas. These will soon be taken up and stored for plantation in the same manner as the preceding; whether the feculent black bryony root can be made edible remains to be proved

Plot A^1. *Parsnips* in seed.—This is a plot of my ennobled wild parsnips, experiments connected with which were reported upon in 1856. The last year's experimental plot was so fine that the whole of it was left for seed; while

Plot A^2 is a large piece of parsnips in the kitchen garden from my seed of 1856: here the new parsnips promise to be very large and clean in the skin, the College gardener now preferring it to any other kind, as this new offspring of the insignificant wild root is much richer in flavour than the older varieties, which are wearing out in this respect. My roots now offer examples both of "long horn" and "short horn" varieties, so that another year I shall be enabled to save seed of two distinct and newly induced varieties.

Grasses.—The experimental plots of grasses which have been already reported upon, maintain their induced characters most perfectly, and I have become still more convinced of the little value to be placed in the specific characters of these plants as laid down by botanists, while at the same time I am fully aware how easy it is to make permanent varieties. In experimenting upon these, however, it must be admitted that there are great difficulties in the way, arising from the facility with which they become mixed with one another, and altogether the trouble there is in keeping the plots clean; still the changes in *Oats* and in the *Poa aquatica* cannot be vitiated on this account, as their descendants are not like anything around them; the *Poa*, indeed, is altogether new; we have no grass in the British Flora at all like the specimens I now submit to the Section. This is, in fact, as much a new and distinct species as the most specific of our well-known forms, and yet its production is perfectly under control, and that not, as has been hinted, as an isolated specimen, but in whole patches.

Plots B^1 and C^1 are of this descendant from *Poa aquatica*, and fine grasses they are; they have already been laid before the Section, with the seeds whence they were derived in 1857; but these experiments, and all upon the grasses, will be again repeated on a new patch of ground which is clearing for the purpose; and if I can but get good seeds, I anticipate a great deal of new matter from this source.

Plot D^1 is *Poa aquatica* from plants taken from the canal side; they are growing very well; but even from growing in an unaccustomed habitat, they are taking on immense differences, which I expect time will confirm; I shall therefore reserve any further description of this until another opportunity.

Plots D^1, E^1, F^1, were devoted to oat experiments as follows:—

D^1. *Avena fatua*, var. *sativa*. Tartarean sort.

E^1. *Avena fatua*, var. *sativa*. Potato sort.

F^1. *Avena fatua*, formerly *sativa*. Left wild as a permanent crop.

Of these, D^1 and E^1 have maintained their characters both in my experimental plots and in the extended farm cultivation to which they have been subjected by Mr. Coleman, the Manager of the Royal Agricultural College Farm.

Plot F^1 has presented all phases of reversion, just as may be observed in the field on examining the offspring of 'shed' oats.

Plot G^1 is occupied with a grass which has recently excited some attention, it is the *Holcus* (*Sorghum*) *saccharatus*: its seed was drilled early in April, and duly thinned out as it advanced. Early in August it had stooled to about five culms to each plant, of which the main or primitive one was the largest; at this time I gathered some in order to try how the cows liked it; but they uniformly refused it, which was not to be wondered at, when at this time the whole of my plants possessed an intensely bitter taste. On the 1st of September I again made trial with some of the more advanced shoots; they were devoured greedily, but now an immense quantity of sugar had been developed, as the bases of these tasted quite as sweet as liquorice root. This points to the circumstances that the juices of this plant may be rich in saccharine matter at a later, though not at an earlier stage of growth; if, then, it is ever to be useful as a feeding grass, this must be attended to; but I much doubt whether at any time in the cold climate of the Cotteswolds this species of sugar-cane will yield so much sugar as in a warmer and less exposed position; at the same time, as a first trial, I consider this eminently successful, and I should not wonder to see it more fully tried over a great part of England next season.

Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops. *By* Dr. AUGUSTUS VOELCKER, *Royal Agricultural College, Cirencester.*

THE field experiments on which I have to report were begun in 1855, and have been continued since from year to year. They were at first instituted chiefly for the purpose of ascertaining practically the comparative economic value of some of the artificial manures, such as guano, superphosphate of lime, bone-dust, &c., in reference to root-crops. In the course of my experiments, however, I was led to abandon, more or less, the primary object for which the experiments were at first undertaken, and to make them subservient to assist the solution of several disputed and important points in agricultural and physiological science.

Amongst other questions which arise in the mind of the agricultural chemist who has closely followed the progress of agricultural chemistry, the following are some of the more important:—

1. Can ammonia or nitrogenized matters be dispensed with in manures, or is it desirable that there should be a certain proportion of nitrogenized matter or ammonia in manures?

2. What is the effect of ammoniacal salts, of phosphates, of alkalies, and other fertilizing constituents applied separately upon vegetation?

3. Is the practical effect produced by ammonia, or by phosphates, &c., the same upon wheat or other grain crops as that produced upon turnips or clover?

4. Are there fertilizing constituents which benefit certain crops more than others?

5. Is it desirable or unphilosophical, and therefore leading to the ultimate exhaustion of the soil, to apply special fertilizing matters to the land, *i. e.* matters which contain but 1, 2, or at all events a limited number of chemical compounds? or is it necessary, in order to maintain the permanent fertility of the land, to restore to the soil in the shape of a compound and universal manure, all the constituents removed by the crops grown upon the land in previous years? These and other similar questions, affecting agricultural practice, have occupied me for several years past.

The results of my experiments detailed in the following Report, I trust will be found useful contributions towards the final settlement of the mooted questions.

Field Experiments made in 1855.

Although I believe that the minute chemical analysis of soils, generally speaking, affords but little or no indication as to the fertilizing matters which are best calculated to improve their productive powers, I am still of opinion that it is desirable and even indispensable to record in all field experiments, the principal physical characters, and the amount of at least the chief or preponderating constituents of the soil of the experimental field.

I would therefore observe that the experimental field was a naturally poor shallow soil with clayey subsoil of inconsiderable depth, and resting on the Great Oolite limestone rock.

Submitted to a general analysis, it yielded—

Organic matter and water of combination	6·339
Oxides of iron and alumina, with traces of phosphoric acid	9·311
Carbonate of lime	54·566
Magnesia, Alkalies, Sulphuric acid } determined by loss	·837
Insoluble siliceous matter (chiefly clay)	28·947
	100·000

The land was left unmanured in the preceding year, and was considered a poor turnip soil.

I purposely selected a poor field; for it strikes me on such a soil the manurial effect of different fertilizers is much better discerned than on land in a high state of fertility. The productive power of soils cannot be increased to an unlimited extent; and when by good cultivation it approaches its maximum state of fertility, the addition of the most effective fertilizing matters cannot produce any marked effect. I may, however, observe that care was bestowed upon the mechanical preparation of the land, which is not always done in field experiments.

The experimental field was divided into ten different plots of one-eighth of an acre each. These plots were arranged side by side in continuous rows of drills, care being taken to reject the headlands. The different manures were all applied to the land on the same day, and the Swedish turnip-seed sown by a ridge-drill on the 20th of June. Subsequently all the plots were treated in precisely the same way, and care was taken to render the experiments in every respect comparative.

One of the plots was left unmanured, the nine remaining were manured as follows:—

Plot 1 received 56 lbs. of Peruvian guano, or at the rate of 4 cwt. per acre.

Plot 2 received 84 lbs. of Suffolk coprolites, treated with one-third their weight of sulphuric acid and 28 lbs. of guano, or at the rate of 6 cwt. of dissolved coprolites and 2 cwt. of Peruvian guano per acre.

Plot 3 received 100 lbs. of bone-dust, or 7 cwt. 16 lbs. per acre.

Plot 4 received 93 lbs. of bone-dust dissolved in one-third its weight of sulphuric acid, or at the rate of 6 cwt. 72 lbs. per acre.

Plot 5 received 56 lbs. of economical manure, or at the rate of 4 cwt. per acre.

Plot 6 received 120 lbs. of nut-cake, or at the rate of 8 cwt. 64 lbs. per acre.

Plot 7 was manured with 140 lbs. of dissolved coprolites, or at the rate of 10 cwt. per acre.

Plot 8 was left unmanured.

Plot 9 received 180 lbs. of commercial night-soil manure, or at the rate of 12 cwt. 96 lbs. per acre.

Plot 10 was manured with a mixture of 1 bushel of soot, 30 lbs. of guano, and dissolved coprolites and dissolved bones.

The respective quantities of these fertilizing matters were all obtained at the same cost of *5s.* per plot, or at the rate of £2 per acre.

All the different fertilizers were carefully analysed; but in order not to swell too much this Report I abstain from giving the details of the analyses. I may, however, observe that the guano contained 14·177 per cent. of nitrogen, and 25·06 of bone-earth, and nearly 3 per cent. of phosphoric acid in combination with alkalies. We have thus in Plot 1 a manure containing a large proportion of nitrogenized matters as well as phosphates and alkalies.

In Plot 2 only half the amount of guano was used, and phosphates more largely supplied in the shape of dissolved coprolites.

The coprolites, however, having been treated with only one-third their weight of acid, contained scarcely more than 6 per cent. of soluble phosphates; and it is to be feared that the remainder of the undissolved phosphates in the coprolites exercised little or no effect upon the turnip-crop.

In Plot 3 we have a manure which contains 44·22 of insoluble phosphate of lime, and 4·28 per cent. of nitrogen.

In Plot 4 bone-dust dissolved in one-third its weight of sulphuric acid, consequently a manure which contained both soluble and insoluble phosphates, was employed.

The economical manure, a manure highly recommended for the growth of root-crops, and used upon Plot 5, contained in 100 parts—

Water	36·525
Protosulphate of iron	23·756
Sulphate of lime	·860
Sulphate of magnesia	·204
Bisulphate of potash	4·677
Bisulphate of soda	10·928
Sulphate of soda	15·143
Sulphate of ammonia	2·648
Insoluble siliceous matter (sand)	5·850
	100·591

This manure thus contained no phosphoric acid whatever.

In Plot 6 nut-cake was used. This refuse manure contained 4·863 per cent. of nitrogen and 4·12 of phosphate of lime.

The dissolved coprolites used in Plot 7 were free from nitrogenized matter.

In the commercial night-soil manure was found 4·399 per cent. of phosphoric acid.

The whole produce of each experimental plot was weighed, and the weight of the trimmed roots calculated per acre.

The following Table exhibits the yield of the trimmed roots of each plot, calculated per acre, and the increase per acre over unmanured plot:—

	Per acre.			Increase per acre.		
	tons.	cwt.	lbs.	tons.	cwt.	lbs.
Plot 1 (guano) yielded	11	12	56	6	8	56
Plot 2 (guano and dissolved coprolites) yielded	12	16	16	7	12	16
Plot 3 (bone-dust) yielded	8	16	0	3	12	0
Plot 4 (bone-superphosphate) yielded	13	12	16	8	8	16
Plot 5 (economical manure) yielded	6	0	16	0	16	16
Plot 6 (nut-cake) yielded	10	0	0	4	16	0
Plot 7 (dissolved coprolites) yielded	11	12	0	6	8	0
Plot 8 (unmanured) yielded	5	4	0			
Plot 9 (commercial night-soil) yielded	9	4	0	4	0	0
Plot 10 (mixture of soot, guano, dissolved coprolites and bone-superphosphates) yielded	10	0	8	4	16	8

It will appear from these experiments—

1. That phosphatic manures greatly increased the yield of the root-crop.

2. That a purely mineral phosphate, when dissolved in acid and quite free from ammonia, gave as large a return as good Peruvian guano, which is rich in ammonia.

3. That the economical manure, which contained no phosphates, practically speaking, gave no increase in the crop.

4. That manures which are comparatively poor in phosphates produced less effect than manures rich in phosphates.

5. That the form in which the phosphates were employed very much affected the result.

Thus bone-dust treated with sulphuric acid, and consequently containing soluble phosphates, yielded an increase of 8 tons. 8 cwt. 16 lbs. over unmanured plot, whereas an equal money value of bone-dust undissolved yielded an increase of only 3 tons 12 cwt.

6. That guano proved to be a less economical manure for Swedes than superphosphate.

Experiments upon Swedes made in 1856.

The preceding experiments sufficiently show the great importance of phosphates presented in a soluble condition to the crop of Swedes. They appear likewise to indicate that nitrogenized or ammoniacal manures are not so essential as phosphates for the production of a good crop of roots; but they do not touch the question whether or not ammonia can be entirely dispensed with in the cultivation of turnips. This is an important question, for of all fertilizing matters ammonia is the most expensive.

My attention therefore was chiefly directed in the next series of experiments to study the influence which purely ammoniacal manures exert on the growth of Swedish turnips.

Reviewing the experiments made in 1855, it may appear that the nitrogenized matters and ammonia contained in the manures employed had some share in the production of the increase; for it will be remembered that the addition of a small quantity of guano to dissolved coprolites had a very beneficial effect. Again, the fact that bone-superphosphate, containing from 2 to $2\frac{1}{2}$ per cent. of ammonia, gave a much larger return than the mineral superphosphate, might seem to indicate that ammonia in moderate proportion is a desirable fertilizing ingredient of a turnip manure.

A critical examination of these facts, however, I think neither proves nor discountenances the conclusion that ammonia has had a beneficial effect on the recorded experiments; for when comparing the effects of bone-superphosphate with dissolved coprolites, no account was taken of the proportion of soluble phosphate contained in each. I have since ascertained that the dissolved coprolites contained most of the phosphate in an insoluble state, not near enough acid having been employed for dissolving the coprolite powder. Indeed the coprolite manure contained but little soluble phosphate; and as insoluble phosphate, in the shape of coprolite powder, has little or no effect upon vegetation, whilst the insoluble phosphates in bone-dust, partially decomposed by acid, unquestionably are sufficiently available to produce an immediate effect on the turnip crop, the difference in the result may have been due to the larger amount of available phosphates, and not to the ammonia contained in the bone-phosphate. On the other hand, the addition of some guano to dissolved coprolites having produced a beneficial effect, it may be inferred that the ammonia in the guano helped to produce this effect; but since Peruvian guano contains both soluble phosphates and insoluble phosphate of lime in a highly finely-divided state, it may be maintained with equal force that the additional produce resulted from the additional quantity of available phosphates in guano. In short, the experiments in 1855 are not calculated to decide the question whether or not ammonia can be dispensed with as a manuring constituent in a turnip manure.

With a view of throwing some light on the action of ammonia on root-crops, I made in 1856 the following field experiments:—

A portion of a field was divided into twelve parts of one-twentieth of an acre each. The seed was sown on the 21st of June.

The soil on analysis yielded the subjoined results:—

Moisture when analysed	4·72	
Organic matter and water of combination	11·03	
Oxides of iron	9·98	
Alumina	6·06	
Carbonate of lime	12·10	
Sulphate of lime	·75	
Alkalies and magnesia (determined by loss)	1·43	
Silica (soluble in dilute caustic potash)	17·93	
Insoluble siliceous matter (chiefly clay)	36·00	
		100·00

The experimental field was well drained. The surface soil is thin, poor, and full of fragments of limestone, which render the land lighter. Separated from the stones, the soil may be regarded as a stiffish clay-marl, which in wet weather is very tenacious and heavy, and in warm weather dries into hard unmanageable lumps. The depth of the soil was inconsiderable.

The twelve experimental plots were treated in regard to manure as follows:—

		At the rate of per acre.
To Plot 1 was applied well-rotten farmyard manure		15 tons.
To Plot 2 was applied gypsum		6 cwt.
To Plot 3 was applied bone-ash dissolved in sulphuric acid		6 cwt.
To Plot 4 was applied sulphate of ammonia		6 cwt.
To Plot 5 was applied bone-ash dissolved in sulphuric acid	6 cwt.	
and sulphate of ammonia	6 cwt.	—12 cwt.
To Plot 6 was applied bone-ash dissolved in sulphuric acid		12 cwt.
To Plot 7 was applied sulphate of potash		6 cwt.
Plot 8 (unmanured).		
To Plot 9 was applied crystallized sulphate of soda		12 cwt.
To Plot 10 was applied bone-ash dissolved in acid	6 cwt.	
sulphate of potash	6 cwt.	
sulphate of ammonia	6 cwt.	—18 cwt.
To Plot 11 was applied bone-ash dissolved in acid		3 cwt.
Plot 12 (unmanured).		

The dissolved bone-ash on analysis yielded the following results:—

Water	32·80	
Organic matter	·13	
Biphosphate of lime (CaO, PO_5)	18·49	
Equal to bone-earth rendered soluble by acid	(28·80)	
Insoluble phosphates	6·43	
Hydrated sulphate of lime	38·39	
Alkaline salts	1·94	
Sand	1·82	
		100·00

This preparation thus contained a large per-centage of soluble phosphate as well as gypsum, which necessarily must be formed when bone-ash is dissolved in acid. It having been stated by a high authority that in Messrs. Lawes and Gilbert's turnip experiments the sulphate of lime contained in their superphosphate might have had quite as much influence upon the produce as the phosphate of lime, it appeared to me desirable to apply gypsum alone to one plot. Turnips contain a considerable quantity of sulphur; it is therefore not unlikely that in soils deficient in sulphate of lime, the artificial supply of sulphates may be found advantageous to the turnip crop. At the same time it appeared to me desirable to ascertain the effects of alkalies on turnips, and ammonia, potash, and soda applied in the shape of sulphates. We have thus in these experiments sulphuric acid in all the different states of combination in which it is likely to occur in arable land.

Two plots, it will be noticed, were left unmanured. This should always be done in field experiments; for otherwise it is impossible to ascertain whether or not an experimental field is uniform, and what are the unavoidable variations in the produce of two plots of the same field.

It will be noticed that in nearly all plots nothing but simple salts were used, in order not to complicate the interpretation of the results. It is useful, however, to ascertain how far the natural produce may be increased by a compound and approved fertilizer, such as farmyard manure, and in such an experiment ordinary manure should be as liberally supplied as in Plot 1.

The Swedes were taken up in the last week of November, topped and tailed, and the whole produce of each plot weighed.

Table, showing the produce of trimmed Swedes of Experimental Plots, calculated per acre, and increase over the unmanured part of field.

	tons cwt. lbs.	tons cwt. lbs.
Plot 1 (15 tons of farmyard manure) yielded	7 16 38	5 0 75
Plot 2 (6 cwt. of gypsum) yielded	2 1 45	Decrease. 0 11 30
Plot 3 (6 cwt. of dissolved bone-ash) yielded	8 3 38	5 7 40
Plot 4 (6 cwt. of sulphate of ammonia) yielded ..	2 12 51	Decrease. 0 3 24
Plot 5 (6 cwt. of sulphate of ammonia, and 6 cwt. of dissolved bone-ash) yielded	8 6 41	5 10 78
Plot 6 (12 cwt. of dissolved bone-ash) yielded ..	8 12 90	5 17 15
Plot 7 (6 cwt. of sulphate of potash) yielded	2 10 0	Decrease. 0 5 75
Plot 8 (unmanured) yielded	3 0 19	
Plot 9 (12 cwt. of crystallized sulphate of soda) yielded	3 6 9	0 10 46
Plot 10 (6 cwt. of dissolved bone-ash, 6 cwt. of sulphate of ammonia, 6 cwt. of sulphate of potash) yielded	6 17 6	4 2 43
Plot 11 (3 cwt. of dissolved bone-ash) yielded ..	7 19 51	5 4 88
Plot 12 (unmanured) yielded	2 11 19	

The natural produce of the experimental field was taken at 2 tons 15 cwt. 75 lbs., being the average of the two unmanured plots No. 8 and 12.

These results suggest the following remarks:—

1. The natural produce of this field was very small, as it scarcely amounted to 3 tons per acre; special fertilizing ingredients, such as phosphoric acid, ammonia, &c., therefore may be expected to have full play in a soil like the one of the experimental field.

2. Only those plots yielded an increase which contained phosphates; the other manuring constituents had no effect upon the turnip crop in these experiments.

3. Gypsum cannot replace phosphate of lime in manuring matters. In these experiments it had no effect whatever, which need not surprise if it be remembered that the soil contained naturally $\frac{3}{4}$ of a per cent. of sulphate of lime.

4. None of the other sulphates produced any effect upon the crop. Sulphates, especially sulphate of lime, are much more abundant in nature than phosphates. There are few soils which do not contain abundance of sulphate

of lime to supply our cultivated crops with abundance of sulphuric acid. This appears to me the chief reason why sulphates rarely show any effect upon turnips and other crops.

5. The bone-ash dissolved in acid did not contain any nitrogen, notwithstanding 3 cwt. produced as large an increase as 15 tons of well-rotten farmyard manure.

6. Sulphate of ammonia proved inefficacious when used by itself, or in conjunction with soluble phosphates.

It is possible, however, that the quantity of ammonia used in the experiments was too large. Similar experiments, which I have since undertaken and hope to continue for a number of years, induce me to believe that on the soils in our neighbourhood ammonia has no beneficial effect whatever upon Swedes. And yet it is quite possible that ammonia may prove beneficial on other soils, which, like sandy soils, do not possess in a high degree the power of absorbing ammonia from the atmosphere, nor to accumulate largely nitrogenized organic matters. But the cases in which ammonia or nitrogenized manures are really beneficial to turnips I think are quite exceptional; and I have little hesitation in saying that a great deal of ammonia, the most expensive fertilizing ingredient of guano, at the present time is wasted in most instances in which guano and other ammoniacal manures are exclusively employed in the cultivation of root-crops.

It is certainly a remarkable fact that many thousands of tons of turnips are now raised annually with nothing else but 3 cwt. or 4 cwt. of superphosphate, made exclusively of bone-ash and mineral phosphates.

At least 90 per cent. of all the artificial manures that are now offered for sale, whatever their name may be, are in reality superphosphates; and the great majority of superphosphates contains no appreciable amount of nitrogen. Even those artificial manures which, like nitro-phosphate, ammonio-phosphate, blood-manure, &c., convey the idea of manures rich in nitrogen or ammonia, when prepared for turnips, seldom contain any considerable amount of nitrogen. It is not likely that an intelligent class of men like the makers of artificial manures, would cut short the supply of nitrogenized matters or ammoniacal salts in turnip-manures, if they had not found out by experience that manures made from bone-ash and sulphuric acid alone, and consequently rich in soluble phosphates, have a more powerful influence upon the yield of root-crops than ammoniacal manures, which are comparatively poor in phosphates.

I would likewise specially notice, that even quite dilute solutions of ammoniacal salts retard the germination and early growth of turnips in a remarkable degree.

In the preceding experiments I was surprised to find, contrary to all expectation, that sulphate of ammonia impaired the development of leaves. Ammoniacal salts are generally considered as leaf-producing, fertilizing constituents; I therefore fully expected to see on Plot 4 a luxuriant development of tops on the expanse of the bulbs. But not only did sulphate of ammonia retard the germination of the seed for a short period, instead of pushing it on rapidly, but throughout the whole season the turnip-tops on Plot 4 looked quite as bad, if not worse, than the unmanured plot.

However, in Plot 5, in which sulphate of ammonia was used in conjunction with dissolved bone-ash, I observed, to some extent, the effects which are generally ascribed to ammoniacal manures. The leaves of the turnips in Plot 5 had a much darker appearance than in other plots not dressed with ammoniacal salts, and the plants on this plot, on the whole, looked the most luxuriant.

It would appear from this that ammoniacal salts are useless by themselves as leaf-producing substances, when applied to poor soils deficient in phosphates and other mineral matters necessary for the growth of leaves.

In conjunction with phosphates, sulphate of ammonia in the preceding experiment had a marked effect upon the turnip-tops, but none upon the bulbs.

Experiments on Turnips made in 1857.

My experiments in 1857 were principally made with a view of trying whether sulphate of ammonia, applied alone and in conjunction with phosphates, had the same or a similar effect on richer land than that experimented upon in 1856, and at the same time to determine the influence of nitrogenized matters on the turnip crop. To this end I selected a field which was somewhat deeper, more level, and altogether more fertile than the experimental field in 1856. It yielded on analysis the following results:—

Moisture	1·51
Organic matter and water of combination	11·08
Oxides of iron and alumina	14·25
Carbonate of lime	10·82
Sulphate of lime	·71
Magnesia	·51
Potash (soluble in acid solution)	·32
Soda (soluble in acid solution)	·05
Phosphoric acid	·10
Insoluble siliceous matter (chiefly clay)	61·78
	101·13

On comparing the composition of this soil with that of the experimental field in 1856, it will be found that the chemical characters of both soils are very much alike. The seed sown on the 10th of June was that of white Swedes. The different manures were mixed with three times their weight of fine sifted burnt clay, in order to secure a more uniform distribution of the manure over the land. Each experimental plot measured $\frac{1}{20}$ of an acre. Leaving unnoticed a number of field trials, I select only those experiments which have a more immediate scientific interest.

Plot 1 was manured at the rate per acre with 3 cwt. of superphosphate.

Plot 2 was manured at the rate per acre with 3 cwt. of fine bone-dust.

Plot 3 was manured at the rate per acre with 3 cwt. of superphosphate, made by dissolving fine bone-dust in 50 per cent. of sulphuric acid.

Plot 4 was manured at the rate per acre with 3 cwt. of bone-superphosphate (purchased).

Plot 5 (unmanured).

Plot 6 was manured at the rate per acre with $1\frac{1}{2}$ cwt. of sulphate of ammonia.

Plot 7 was manured at the rate per acre with $1\frac{1}{2}$ cwt. of sulphate of ammonia and $1\frac{1}{2}$ cwt. of superphosphate, made by dissolving bone-ash in sulphuric acid.

Plot 8 was manured at the rate per acre with $1\frac{1}{2}$ cwt. of bone-ash dissolved in sulphuric acid without ammonia.

Plot 9 was manured at the rate per acre with 4 cwt. of gypsum.

Plot 10 was manured at the rate per acre with 9 cwt. of burnt clay alone (the same quantity which was used with the manures in the other experiments).

Plot 11 was manured at the rate per acre with 3 cwt. of Peruvian guano.

On each plot a good plant was obtained, and the crop singled on the 16th of July, with the exception of the plots upon which sulphate of ammonia and guano were used. Although sulphate of ammonia was used in the small proportion of $1\frac{1}{2}$ cwt. per acre, and previously mixed with three times its weight of burnt clay, it retarded the germination of the seed and the growth of the turnips in their first period of existence. Several other experiments, made on a small scale, and all my experiments upon turnips in 1858 and in 1859, confirm the fact first observed by me in 1855, that sulphate of ammonia, instead of rapidly pushing on the young plant, as generally supposed, retards its development in a very marked degree.

The produce of each plot was taken up on the 19th of November; after trimming and cleaning, the roots were weighed. The following Table gives the produce in Swedes, topped and tailed, and cleaned per acre, and increase per acre:—

Plot.	tons.	cwt.	qrs.	lbs.		Increase per acre. tons.	cwt.	qrs.	lbs.
1. 3 cwt. of superphosphate	10	17	0	16	...	4	5	1	20
2. 3 cwt. of bone-dust	8	11	0	26	...	1	19	2	2
3. 3 cwt. of superphosphate, made by dissolving bone-dust in 50 per cent. sulphuric acid	9	14	3	1	...	3	3	0	5
4. 3 cwt. of purchased bone-superphosphate	9	17	2	2	...	3	5	3	6
5. Unmanured	6	11	2	24			Decrease.		
6. 1½ cwt. of sulphate of ammonia	5	6	0	21	...	1	5	2	3
7. 1½ cwt. of sulphate of ammonia and 1½ dissolved bone-ash	9	3	0	26	...	2	Increase. 11	2	2
8. 1½ cwt. dissolved bone-ash	8	18	3	22	...	2	7	0	26
9. 4 cwt. of gypsum	6	13	3	17	...	0	2	0	21
10. 9 cwt. of burnt clay	6	16	3	1	...	0	5	0	5
11. 3 cwt. of Peruvian guano	8	18	1	25	..	2	6	3	1

Plot 1, it will be seen, yielded the largest increase; from first to last this plot had the lead as to appearance.

The superphosphate used in this experiment had the following composition:—

Moisture	10·80
Organic matter*	4·21
Biphosphate of lime	20·28
Equal to bone-earth made soluble by acid	(31·63)
Insoluble phosphates	4·11
Hydrated sulphate of lime	46·63
Common salt	10·78
Sand	3·19
	100·00

It will be seen that there is very little nitrogen in this superphosphate, and that in addition to much soluble phosphate it contains about 11 per cent. of common salt. Salt, I am inclined to think, increases the efficacy of phosphates upon turnips.

Plot 2. The bone-dust used upon this plot was as fine as sawdust, and yielded on analysis,—

Moisture	6·86
Organic matter†	13·14
Phosphates of lime and magnesia	68·17
Carbonate of lime	6·79
Alkaline salts	1·90
Sand	3·42
	100·00

* Containing nitrogen .... ·34
Equal to ammonia .... ·41

† Containing nitrogen ...... 1·83
Equal to ammonia ...... 2·22

Plot 3. A comparison of the produce of Plot 3 with Plot 2 will show the advantage of applying the phosphates to the land in a condition in which they are readily distributed in the soil by the rain that falls, and more easily dissolved in water than the phosphates in bone-dust.

These dissolved bones gave on analysis the following results:—

Water	24·33	
Organic matter and ammoniacal salts*	5·04	
Biphosphate of lime	17·00	
Equal to bone-earth rendered soluble by acid	(26·52)	
Insoluble phosphates	9·89	
Hydrated sulphate of lime	39·25	
Alkaline salts and magnesia	2·81	
Sand	1·68	
		100·00

Plot 5 (unmanured) gave 6 tons 11 cwt. 2 qrs. 24 lbs.

Plot 9 (gypsum) gave 6 tons 13 cwt. 3 qrs. 22 lbs.

Plot 10 (burnt clay) gave 6 tons 16 cwt. 3 qrs. 1 lb.

The produce of these three plots is so much alike, that the small difference may be safely ascribed to natural variations of the soil. The crop on these plots again shows that gypsum had no effect, and that the experimental field was uniform in its character.

Plot 6. The sulphate of ammonia used in this experiment contained in 100 parts,—

Sulphate of ammonia	98·28	
Fixed salts	·78	
Moisture	·94	
		100·00

We have here actually a decrease of 1 ton 5 cwt. 2 qrs. 3 lbs. of roots per acre. The plants on this plot, I may observe, came up much later, and looked decidedly worse than those on the unmanured plot, or any other part of the experimental field.

It will be remembered that in the preceding season sulphate of ammonia did not increase the yield in bulbs, and likewise prevented the development of luxuriant tops.

Plot 7. The addition of sulphate of ammonia to dissolved bone-ash, it will be seen by comparing the yield of this plot with that of Plot 8, gave but a slight increase, amounting to no more than 4 cwt. 1 qr. 6 lbs. per acre.

Plot 8. The dissolved bone-ash used in this experiment was the same as that used in experiments in the preceding year, and contained—

Biphosphate of lime	18·49
Equal to soluble bone-earth	(28·80)
Insoluble phosphates	6·43

It did not contain any nitrogenized constituents.

Plot 11. The Peruvian guano used upon this plot yielded on analysis,—

Moisture	18·50	
Organic matter and ammoniacal salts†	52·33	
Phosphate of lime and magnesia	21·66	
Alkaline salts‡	6·41	
Insoluble siliceous matter	1·10	
		100·00

* Containing nitrogen .... 1·28
Equal to ammonia........... 1·55

† Containing nitrogen...... 14·16
Equal to ammonia........ 17·19

‡ Containing phosphoric acid .... 1·46

The roots on this plot were for a long time decidedly inferior to the superphosphate turnips. But towards the middle of September the plants took a start, and the guano turnips, so far as the tops were concerned, looked the best in the field. When the crop was taken up, the guano turnips were at least 3 inches higher in the tops, and promised, as far as appearance went, the heaviest crop; but the actual weight of the plots manured with dissolved bone-ash and superphosphate not containing any nitrogenized matters, showed that there was no advantage in using ammoniacal matters for producing good bulbs on the experimental field.

The whole tenor of the field trials in 1857 agrees well with the results of the trials in 1856. The experiments in 1859 afford a fresh proof that salts of ammonia applied alone to root-crops have no beneficial effect, but rather the reverse. They also show that phosphate of lime in a soluble state favours more the production of good bulbs than any other manuring constituent, and that nitrogenized matters are not required in a manure for Swedish turnips, grown on land similar to the experimental field, and under conditions similar to those which prevailed in 1856 and 1857.

In concluding this part of my Report, I may state that last year (1858) the results of my field experiments were entirely spoiled by the ravages which the fly and the black caterpillar committed.

This year (1859) I have an extensive series of field experiments upon Swedes. All the experimental plots look remarkably healthy, and I hope in a future year to repeat the result of this year's trials, which were made like those in 1856, 1857, and 1858, with a special view of determining the influence of nitrogenized substances and ammoniacal salts on root-crops.

Before proceeding with another series of field experiments, I may state that I have analysed at various times hundreds of turnips. It would be occupying too much space to give here tabulated abstracts of these analyses. Although I am still occupied with following up this examination of turnips grown under various conditions, and have not as yet arrived at any definite conclusions respecting the influence of different manuring matters on this crop, I may state a few general facts which my analyses have brought to light.

1. In the first place, I would observe that I do not find any striking differences in the composition of roots raised with different manures, provided they are pulled up in an equally mature condition.

2. Soluble phosphates appear to promote an early maturity of the roots, and ammoniacal salts, on the contrary, to retard the maturity of roots. However, on this point my experiments are not sufficiently numerous and conclusive to establish satisfactorily this matter.

3. Roots grown on poor soils and developed more gradually, contain less water and more sugar, and are consequently more nutritious than roots of a large size grown rapidly with much manure.

4. Contrary to a very prevalent opinion, I find that the best and most nutritious roots invariably contain less nitrogen than inferior less nutritious roots. Indeed I am of opinion that a high per-centage of nitrogen in turnips is a sure sign that the roots have not reached full maturity, and are less wholesome to cattle than well-ripened roots. In the latter I have found, in some instances, fully one-third less of nitrogen than in the same roots at an earlier stage of their growth.

The examination of roots, taken once every fortnight from the same field during several successive months, has shown that the per-centage of nitrogen in turnips steadily decreases in the measure in which they proceed towards maturity. In the measure in which the per-centage of nitrogen decreases, that of sugar increases. Thus in mangolds, which were as yet scarcely sweet to the taste, I have found as much as $2\frac{3}{4}$ per cent. of nitrogen in the dry roots, whilst in the best and fully ripe mangold wurzels only 1·30 per cent. of nitrogen was found.

The nutritive value of different roots, therefore, is not dependent on the relative proportion of nitrogen which they contain, but is regulated chiefly by the relative proportion of sugar which they yield.

Field Experiments upon Wheat made in 1859.

I have now to record the results of a series of experiments upon the wheat-crop.

The field upon which the experiments were made was perfectly level, and apparently of uniform depth and agricultural capability.

It was divided into seven plots of $\frac{1}{4}$ of an acre each.

Plot 1 was manured with Peruvian guano at the rate of $2\frac{1}{2}$ cwt. per acre; cost £1 12*s.* 6*d.* per cwt.

Plot 2 was manured with nitrate of soda, $1\frac{3}{4}$ cwt.

Plot 3 was manured with nitrate of soda, 180 lbs., and common salt, $1\frac{1}{2}$ cwt.; cost £1 12*s.* 6*d.*

Plot 4 was manured with wheat-manure specially prepared, and containing both mineral and ammoniacal constituents, at the rate of 4 cwt. per acre.

Plot 5 was manured with the same wheat-manure, at the rate of 6 cwt. per acre.

Plot 6 (unmanured).

Plot 7 was manured with chalk-marl, 1 ton.

The nitrate of soda used in the experiments contained 97 per cent. of pure nitrate, and the wheat-manure on analysis was found to contain in 100 parts,—

Composition of Wheat-manure, same as used in Experiments on Royal Agricultural College Farm, March 8, 1859.

Moisture	13·60
Sulphate of ammonia*	10·97
Soluble nitrogenized organic matter†	8·08
Insoluble†	14·72
Biphosphate of lime	3·54
Equal to bone-earth rendered soluble by acid	(5·52)
Insoluble phosphates (bone-earth)	9·45
Sulphate of magnesia	·61
Hydrated sulphate of lime	19·73
Chloride of sodium (common salt)	16·84
Insoluble siliceous matters	2·46
	100·00

The different fertilizers were applied in the shape of top-dressings on the 22nd of March, and the produce reaped in the first week of August and thrashed out on the 24th of August.

* Containing nitrogen	2·32
Equal to ammonia	2·82
† Containing nitrogen	3·53
Equal to ammonia	4·28
Per-centage of anhydrous sulphuric acid (SO_3) in manure (total amount of sulphuric acid in all the sulphates)	15·93
Per-centage of chlorine	10·22
Per-centage of phosphoric acid	8·91

The following Table gives the yield in corn and straw of each experimental plot, the manures employed, and the produce calculated per acre.

Each plot measured $\frac{1}{4}$ of an acre.

	Manures employed and sown, March 22, 1859.	Produce thrashed out, August 24, 1859.
Plot 1.	Peruvian guano, $2\frac{1}{2}$ cwt.; cost £1 12*s.* 6*d.* (guano, £13 per ton).	Grain, 2406 lbs. or $40\frac{1}{10}$ bushels; weight per bushel, 60 to $60\frac{1}{2}$ lbs. Straw, 1 ton 3 cwt.
Plot 2.	Nitrate of soda, $1\frac{3}{4}$ cwt.; cost £1 12*s.* 6*d.* (nitrate of soda, £18 10*s.* per ton).	Grain, 2280 lbs. or 38 bushels; weight per bushel, 60 lbs. Straw, 1 ton 4 cwt. 8 lbs.
Plot 3.	Nitrate of soda, 180 lbs., and chloride of sodium, $1\frac{1}{2}$ cwt.; cost of manure per acre, £1 12*s.* 6*d.* (cost of salt, 30*s.* per ton; of nitrate, £18 10*s.* per ton).	Grain, 2436 lbs. or $40\frac{6}{10}$ bushels; weight per bushel, $60\frac{3}{4}$ lbs. Straw, 1 ton 4 cwt. 48 lbs.
Plot 4.	Wheat-manure, 4 cwt. per acre; cost £1 12*s.* 6*d.* (price of wheat-manure, £8 per ton).	Grain, 2370 lbs. or $39\frac{1}{2}$ bushels; weight per bushel, 60 lbs. Straw, 1 ton 3 cwt. 92 lbs.
Plot 5.	Wheat-manure, 6 cwt. per acre; cost £2 8*s.* (price of wheat-manure, £8 per ton).	Grain, 2652 lbs. or 44 bushels 12 lbs.; weight per bushel, 60 lbs. Straw, 1 ton 7 cwt. 8 lbs.
Plot 6.	Unmanured.	Grain, 1620 lbs. or 27 bushels; weight per bushel, 60 lbs. Straw, 17 cwt. 80 lbs.
Plot 7.	Chalk-marl, 1 ton.	Grain, 1618 lbs. or 27 bushels less 2 lbs.; weight per bushel, $60\frac{1}{2}$ lbs. Straw, 16 cwt. 80 lbs.

A comparison of the different quantities of corn and straw reaped on each experimental plot will show,—

1. That the plot manured with chalk-marl furnished as nearly as possible the same amount of corn and straw as the unmanured plot.

The produce in the one amounted to 1620 lbs. of corn, and in the other to 1618 lbs.; or each gave within 2 lbs. 27 bushels of corn.

In some parts of England chalk-marl is used with considerable benefit for the wheat-crop; but as the soil on the experimental field is full of limestone rubble, it could not be expected that a marl which owes its fertilizing properties almost entirely to the carbonate of lime and to a little phosphate of lime which it contains, should produce any marked effect upon the wheat-crop.

Indeed I did not expect any increase by the application of this marl, and merely used it to ascertain the extent of variation in the produce of two separate plots. The result plainly shows that the experimental field was very uniform in its character and productiveness.

2. The application of only $1\frac{1}{3}$ cwt. of nitrate of soda raised the produce in corn to 38 bushels, and that of straw to 1 ton 4 cwt. 8 lbs.

We have thus here an increase of 11 bushels of corn and $6\frac{1}{4}$ cwt. of straw.

3. By mixing nitrate of soda with common salt, the produce in corn was raised to 40 bushels, thus showing the advantage of a mixture of nitrate of soda with common salt.

4. Almost the same produce as by nitrate of soda and salt was obtained by the application of guano, and by the small quantity of wheat-manure.

By the latter $39\frac{1}{2}$ bushels of corn, and by guano $40\frac{1}{10}$ bushels were obtained, or by the top-dressing with wheat-manure an increase of $12\frac{1}{2}$ bushels; and by that of guano an increase of 13 bushels of corn was obtained at an expense of £1 12*s.* 6*d.*

5. The larger supply of a mixed mineral and ammoniacal fertilizer gave an increase of 17 bushels of corn and 9 cwt. of straw over the yield of the undressed plot.

It will thus appear—

1. That nitrates applied by themselves materially increase the yield of both straw and corn.

2. That the admixture of salt to nitrate of soda is beneficial.

3. That ammonia and nitrogenized matters, which proved ineffective or even injurious in relation to turnips grown on a similar soil on which the wheat was grown, had a most marked and decidedly beneficial effect upon the wheat-crop.

In conclusion, I would observe that I purpose to record the effect of the top-dressings used in the preceding experiments upon the succeeding crops.

Report on the Aberdeen Industrial Feeding Schools.
By ALEXANDER THOMSON, *Esq., of Banchory.*

THE study of the possible prevention of crime has of late years received much attention, though not yet so much as it deserves and requires; nor are the principles on which alone crime can be prevented hitherto fully and generally known and admitted.

One very important movement in connexion with this subject originated in Aberdeen, and it seems appropriate to lay before the Statistical Section of the British Association, when met in Aberdeen, a brief statement of the origin and results of the Aberdeen Industrial Feeding Schools, and of the principles on which they were established and have been conducted.

The origin of these schools was very simple: they arose out of a felt necessity.

Crime in all the large towns of Britain had been visibly increasing for many years in a ratio exceeding that of the increase of the population; a distinctly-marked class or race of criminals had arisen, causing much inconvenience to society, and forcing upon thinking men the consideration of what could be done to check so great an evil.

Several instructive facts gradually became evident. The stern, harsh system of punishment, long prevalent, was found to have failed alike in preventing crime and in reforming criminals, and to have had, on the contrary, the effect of hardening and emboldening in crime those who had been subjected to it, and of thereby forming a distinct class of criminals, marked by peculiar features, and highly injurious to the community.

It was also observed that certain classes of the population produced more than their numerical proportion of criminals.

Nothing, however, attracted so much attention, from the great annoyance which it caused, as the steady increase of the number of youthful offenders, undeniably guilty of actions which deserved punishment, and who evidently required moral and physical treatment of some sort or other, but who by that which had been applied to them were only made worse until they eventually took their places, as they advanced in years, in the ranks of confirmed, bold, dangerous criminals.

Various persons in different parts of the country suggested and tried temporary expedients to remedy the evil, but the first deliberate, consistent, and permanent scheme, combining feeding, teaching, and industrial training, was organized in Aberdeen by Sheriff Watson, and his plan has been found so efficient, that it is now adopted, more or less exactly, in almost every large town in Great Britain.

The immediate cause of this attempt was the pain felt by Mr. Watson, and by many other criminal judges, in the discharge of their ordinary duties. Day after day children of tender years were brought up for trial and convicted of acts undeniably criminal and deserving of punishment, but with regard to which it was very clear that the moral guilt lay not exclusively on the juvenile culprits.

They had no doubt done the deed, but who was most to blame for it? —the actual perpetrator? or those who had allowed or even led to the commission of the offence?

On inquiring into their previous history, it soon became evident, that the root of the evil lay in the want of right parental care and training. The parents were themselves either criminals, or at least wholly careless of their offspring, and left them to grow up as they might, without control, without principle: on the parents clearly lay the primary culpability. Next to them, it lay on the clergymen of all denominations, who, occupied in other and, as they thought, more promising fields of labour, gave a very small share of their time to this particular class; and last, but not least, the blame lay on the professedly christian public of the country, who, as a body, seem to have agreed to regard these outcasts as a Pariah caste beyond the legitimate sphere of christian enterprise; "no man cared for their souls." Noble cases indeed occurred, from time to time, of strenuous and successful exertions on their behalf, but they were isolated, unconnected; and there was no general, no sustained endeavour to reclaim them.

What did these children require? It may be all summed up in three words, "Christian parental care." How was this to be supplied, since the natural parents were unable or unwilling to perform their duties?

There are two opposite dangers to be avoided in applying any remedy: there is the risk on one side of doing too little for the children, so as to fail in training them up aright both bodily and mentally; and there is the not less serious risk on the other, of doing too much, and thereby giving encouragement to listlessness and laziness on the part of the children, and neglect and carelessness on the part of the parents.

To avoid these difficulties, it is needful to ascertain exactly what the children want, and how instruction can be best furnished to them.

For their bodies they need food; for their minds they need instruction in the elementary branches of knowledge; for their success in life they need training in industrial habits, and for their never-dying souls they need abundant religious instruction. This is what their fellow-men can do for them. The saving inspiration of the Holy Spirit can be given only by God himself; it is not at the disposal of mortal man, but is given freely in answer to believing prayer.

These various requisites were all kept in view at the first establishment of the Aberdeen Industrial Feeding Schools, and they have never been for one moment abandoned. They are the foundation-stones on which the whole structure rests; remove any one of them, and the superstructure must fall to the ground; give any one undue preponderance over the rest, and the whole is rendered unsteady and insecure.

In the year 1840 the juvenile criminal population of Aberdeen attracted the particular notice of the local authorities, and many inquiries were made as to their numbers and condition.

In June 1841 it was ascertained that there were in that city 280 children under 14 years of age who supported themselves nominally by begging, but actually to a large extent by stealing, and in either case greatly to the annoyance of their fellow-citizens.

Of these 280 children, 77 had been imprisoned during the previous twelve months.

In October 1841 a small sum, under £100, was collected, and with this it was resolved to try what could be done, confident that, if even a moderate amount of success were attained, public support would be freely given.

Apartments sufficiently extensive, but otherwise of the humblest description, situated in one of the worst districts of the city, were hired, and a teacher engaged. Public notice was given that such an institution existed, and that poor children who chose would be admitted into it, up to the number of 60, and would there receive food, and instruction in elementary religious and secular knowledge, and in such industrial employments as were suited to their years.

Attendance up to the time of the passing of Dunlop's Act in 1854 was wholly voluntary, but the child absent without cause from morning school had no breakfast, from forenoon school had no dinner, and from afternoon school had no supper; and this very simple and reasonable arrangement at once ensured a more regular attendance of pupils than at most common day schools.

The general division of the day was, four hours of lessons, five hours of work, and three substantial meals. The managers did not profess to supply clothing to the children, but, by the kindness of friends, whatever was absolutely necessary was from time to time procured.

Religious teaching and training occupied a large portion of the teaching hours, and has ever been received with the greatest willingness. The whole arrangements are as simple as possible, and yet they meet *all* the requirements of the case.

The combination of food, teaching, and industrial training, form together the distinctive peculiarity of these schools, but the food is practically the foundation of the whole system. The children are not at first alive to the advantages of being taught and trained, but they are thoroughly aware of the benefit of being fed; and this brings them regularly to school. They feel it to be an act of substantial kindness; it at once attaches them to their teacher, and it gradually prepares them to relish and profit by the lessons and work of the school; it convinces them that the school is meant for their good in the only form in which, at first, they are capable of understanding it.

The whole profit of work done goes to defray expenses. This fact is of more value than appears from the amount. It teaches the children from the first that their work is of appreciable value, and also gives them the satisfactory feeling that they are not wholly recipients of charity, but that in return for their food and instruction, they are giving all they can, viz. their labour, such as it is.

It is, however, a great mistake to be too anxious about the earnings of the scholars. That work is most profitable which most tends to habits of patient industry. It matters comparatively little what it may be, provided it teaches steady perseverance, which is the most valuable of all acquirements, and the one most foreign to the habits of neglected outcasts,

Keeping these very simple principles distinctly in view, the first Industrial School was opened 1st October 1841, with 20 scholars, and the number soon rose to 60, the limit previously determined. During the first six months 109 were enrolled, but, as might have been anticipated on a first experiment, some were admitted who were unsuitable, and others whose parents interfered and removed them, and a few whose wandering habits would not allow them to remain more than a few days—not long enough to ascertain whether they would like the school or not; still, with 60 names on the roll, the average daily attendance for the first 6 months was 36 and for the last two 53·50.

The amount realized for work during the first six months was £25 19*s.*, *i. e.* 20*s.* a week, or about 14*s.* 6*d.* for each pupil.

The total cost for each was £4 8*s.* 10*d.*, or, deducting earnings, £3 13*s.* 4*d.*, being at the rate of £7 6*s.* 8*d.* per annum,—a cost which experience soon enabled the directors greatly to reduce.

From 1st April 1842, to 1st April 1843, the average daily attendance was 52, the total cost of each £6 8*s.*, and the earnings £1 2*s.* 8*d.*, leaving the expense of teaching and feeding each boy £5 5*s.* 4*d.* The earnings per head were less than during the first six experimental months, because there was then a larger proportion of stout working boys than have since been admitted, and who were above the age to which the schools have since been exclusively applied.

The close of the year 1843 and commencement of 1844 proved to be the critical period in the history of these schools, and all but fatal to their continuance.

The public interest at first felt in the new scheme had subsided; the experiment was novel, the results uncertain; the subscriptions fell off, and but for the liberal aid given by the magistrates of the city, and the Trustees of the Murtle Charitable Fund, the school must have been closed and the experiment abruptly terminated.

Even with these aids, the directors were obliged to dismiss all but the most necessitous, and reduce the number on the roll from 59 to 35.

The tide was now at its lowest ebb, but it soon began to rise.

No one could occasionally visit the school without remarking the change in the outward appearance of the children, and no one could walk the streets of Aberdeen without noticing a perceptible diminution in the number of troublesome little beggar-urchins. The public came to the conclusion that there was good doing by the experiment, and that, at all events, it should be continued until more certain results were attained, and from that day to this funds have never been wanting; often low enough to require extreme caution in the expenditure, but gradually growing and prospering till the little school on the point of abandonment is now represented in Aberdeen by four schools: a boys' in the House of Refuge, a boys' and girls' at Sugar House Lane, and two separate female schools, having all their valuable and commodious buildings (except those in the House of Refuge), the unencumbered property of the Institutions, and a regular attendance of from 350 to 400 children.

On looking back to the history of the schools, it is found that the circumstances which led the managers to reduce the number of scholars produced more than one very instructive result.

Let us look for a moment at certain statistics from the year 1841 to the year 1851 inclusive.

From the Aberdeen Prison returns it appeared that remarkable variations occurred in the number of juveniles committed. In 1841, when no school existed, the number imprisoned was 61, of whom 26 were natives of the town of Aberdeen, 12 of the county, and 23 were strangers.

For the next ten years, with the schools in operation, the numbers for each year were as follows:—

Year.	Committals to Aberdeen Prison.	Committals to County Prisons.	Total Committed.	Natives of Town of Aberdeen.	Natives of County of Aberdeen.	Strangers.
1842	30	..	30	16	3	11
1843	63	..	63	27	25	11
1844	41	..	41	29	4	8
1845	49	..	49	34	5	10
1846	28	..	28	18	2	8
1847	23	4	27	8	7	12
1848	15	4	19	9	6	4
1849	15	1	16	12	1	3
1850	14	8	22	11	8	3
1851	6	2	8	4	3	1

Turning, on the other hand, to the statistics of the Industrial Schools, it appears that in the first year, with one school in operation, the number of juvenile commitments fell from 61 to 30; that in 1843, when the managers were constrained to reduce the number of scholars, the commitments again rose to even more than in 1841, viz., to 63; that in 1844 and 1845, when the school was restored to a certain measure of efficiency, the numbers fell to 41 and 49, while subsequent returns show that each year after 1845, the number of schools and scholars being greatly increased, the number of commitments went down and down,—28, 23, 15, 15, 14, 6,—the lowest number which has been attained, and of whom only 4 were natives of Aberdeen. The number has subsequently increased, and seems to stand now at about 35, —about half the number when no such school existed,—but last year, 1858, the number fell to 15.

During the first five years after the school was in full operation *not one child who had been in attendance there* was committed to prison, or fell into the hands of the police for any offence. From 80 to 100 children were in constant attendance; they were the very children who formerly had furnished the annual supply of youthful offenders, and yet from among them not one recruit went to join the ranks of criminals, and about 70 had been placed in permanent situations, and were from time to time reported to be self-sustaining and doing well.

These immediate results were more satisfactory than could have been anticipated, or could reasonably be expected to continue; for no one need expect industrial schools to mould every neglected outcast, who passes a few years under their training and teaching influences, into a steady, consistent christian man or woman for life: they, however, greatly cheered the friends of the institutions as they gradually became manifest, and they encouraged them to extend their operations.

While the schools were progressing there were long and very anxious discussions as to whether or not it was desirable to *lodge* the children in connexion with the schools, and only a small majority decided in the negative.

As this is a vital question in the management of industrial schools, it may be well to state briefly the facts and arguments on both sides.

In favour of providing lodgings in the school-buildings there were two principal arguments, both very obvious: 1st, that by thus retaining entire possession of the children their moral training would be carried on before and after school-hours; and 2nd, what was regarded as still more important, that thus they would be preserved from the contaminating influence of their homes, where it was to be feared that the moral lessons learned during the day would be neutralized by evil precept and worse example.

There is so much apparent force in these considerations, that it is only when the subject is viewed in all its relations, and especially when the light of God's word is brought to bear upon it, that a rightful decision of the question can be attained.

The family is the place ordained and prepared by God for the training and up-bringing of children, and this is an ordinance which man can never infringe with impunity.

To collect numbers of children and manage them in masses is sure to destroy individuality of character, while providing *everything* for them effectually destroys energy of character, and prevents the acquirement of habits of industry. Under such treatment abundance of knowledge may be communicated, but no training for the active struggle of life can be given. The whole system is artificial and foreign to the state of that society in which the children are soon to take their places.

The experiment has been fully tried in Scotland by the hospitals so profusely endowed, and long erroneously considered as objects of self-gratulation by every Scotchman, and in England by the poorhouse schools; and in both cases has signally failed. The inmates take their places in the world with their heads stored, it may be, with valuable knowledge, and even quite capable of passing a strict examination in many branches, but with all their energies deadened through want of use, and wholly incapable of applying their knowledge to any useful purpose, unable to rely upon their own exertions because they have been trained up in dependence upon others for all they need.

The first practical lesson to be impressed on the mind of every child, and especially on those who have to support themselves in life by their labour, is that they must, under God, depend on their own exertions for success. In an hospital, or a poorhouse, no such lesson is or can be taught; on the contrary, they are taught practically that they may safely depend for everything on others. This is not the wish nor the intention of the hospital or poorhouse managers, but the necessary result of their systems.

The other aspect of the question, arising from the contamination to be dreaded from a wicked parent's home, is still more serious.

At first sight it looks absurd to train a child carefully for the greater part of the day, and then deliberately, knowingly, to expose him during the remaining hours to see and hear all that is offensive and abominable in the conduct and language of a drunken mother or an abandoned father, or vicious, dissolute neighbours.

If the object to be attained were to train up a child in absolute ignorance of moral evil, then a well-regulated hospital would be exactly what is required; but no man will venture to maintain that this is the sort of training required to adapt a child for a useful life.

Our business is not to train up in ignorance of the existence of evil, but to teach children what sin really is in itself, and in its consequences; how hateful it is to God, how ruinous to man. This is the Bible mode of teaching children as well as men and women, and from that certain rule we never can depart with impunity.

It is most painful to think of the moral evils to be witnessed in many of the dwellings of our crowded cities, and every exertion should be made to cause them to cease; for while they exist they go far to neutralize every effort for the good of the poorest classes, and go on producing a steady supply of neglected juveniles; but that is not the present question; it is, What is the best way of bringing up the children belonging to that class of society and exposed to all these evil influences? Is it by shutting them up for a certain number of years from the knowledge of such things, and then sending them out at once into the midst of them? or is it by teaching them, so far as man can do it, to know and hate sin, and to flee from it?

It is a dangerous step to break up a family, and to tear asunder the ties which bind parents and children together. Few, indeed, are the parents in whose hearts love for their children is wholly extinguished: it survives the destruction of almost every other right feeling in the heart, and it is through this that other good feelings may possibly be rekindled and brought into beneficial operation. It is marvellous to witness the good which flows from the influence of one right feeling beginning to work in a heart which seemed to be seared and dead to every good impression.

Few are the parents who will deliberately teach their children vice and crime; on the contrary, the majority carefully conceal their own wickedness from them. There are few human beings in whom conscience is wholly dead, who do not feel something of the burden of guilt on their own heads, and who would not, if they could, deliver their offspring from it. The principal exception to this is when reason, and every other faculty, is overpowered by strong drink; but even in this case there is the sad, the melancholy advantage, that the children get many a practical lesson of its fearful consequences, and while we deplore the fact, we need not therefore shut our eyes *to this part* of its results.

While this matter was under consideration the further question occurred, What effect will be produced on the wicked parents by the return of the children from the school to their homes? Will it do any good to the parents? More than one case soon became known where unmistakeable benefit arose to the family from the school-children. The parents were interested in hearing what was done at this new school; they saw that at all events their children were well fed for the day, made tolerably clean, and kept out of harm's way. Verses of hymns or texts of Scripture were repeated and listened to; in short, it appeared that the daily return of the child from the Industrial School introduced the first feeble glimmering of improvement at home; it might be only a little sweeping of the floor, or a little arranging of the miscellaneous articles in the room, as they were accustomed to do or to see done at school, but still it was a step in the right direction, an introduction of ameliorating influences. Subsequent experience has shown that some of the children have acted, and are now acting, as little Home Missionaries, conveying the saving truths of the Gospel to parents and brothers and sisters.

It was also discovered that some of the children occasionally denied themselves a portion of their bread and carried it home to supply, so far, the wants of a starving little brother or sister; and here was another humanizing influence brought to bear on the family.

Altogether, the question was under consideration for years, and the ultimate decision was, not to attempt to lodge the children as part of the system, but, in exceptional cases such as orphans, to provide that children should be boarded in a family, and even then only one or two children in one family, unless they were brothers and sisters.

Few such cases have occurred, and they are provided for without encroaching on the general funds.

The decision was no doubt greatly promoted by the managers seeing that they could carry on their work if they did not attempt to *lodge*, but that, if they did, their funds were wholly inadequate to the expense.

It was fortunate on every account that it was so, and the results have been most satisfactory.

While thus fixing the exact extent of their field of labour,—and the general principles on which the work was to be conducted,—the managers were gradually pushing forward their attempts to get under their care all the neglected outcasts in Aberdeen.

The first and most natural step was to commence a school for girls similar to that for boys. It was opened on 5th June 1843, with only three girls, and the number was gradually increased to 20, 40, 50, and at last to 60, the full number for which accommodation was provided.

The results were, if possible, more satisfactory than with the boys. A poor half-starved outcast girl is felt by all to be a more painful sight than a boy in the same condition. She seems to have been forced farther below her right place in society than the boy, and to be less capable of struggling for herself. Experience, however, soon proved that ameliorating influences acted more rapidly, and perhaps more permanently, on the girls than on the boys. The change produced by a few weeks of careful feeding and training upon the most abject was so great, that the ladies who devoted themselves to the arduous enterprise had every encouragement in their work and labour of love.

In December 1844, the first complete year's report of the girls' school stated the number on the roll at 49; and next year, 1845, it was above 60.

During the third year 35 girls left; 16 because their parents had become able to provide for them; 5 got employment in manufactories; and 7 as domestic servants; 7 deserted, and 1 died.

During the fourth year the attendance varied from 56 to 69; 23 left for domestic service, and 31 were removed by parents, as in the previous year; and this must always be regarded as one of the most satisfactory results of the schools, arising either from improved pecuniary circumstances, or from improved moral feeling on the part of the parents.

The expense of each pupil was £3 18*s.* 10$\frac{3}{4}$*d.*, and the earnings of each 6*s.* 11$\frac{1}{2}$*d.*, leaving the net cost to the institution £3 11*s.* 11$\frac{1}{2}$*d.* The amount of earnings was small, but as much as could be expected, considering that nearly half the children were under 9 years of age, most of the rest from 9 to 11, and only 10 of them above eleven. The cost for feeding and teaching the girls was nearly twenty shillings a year less per head than for the boys.

In 1847 circumstances led to a division of the girls' school into two, and both have ever since gone on doing their work effectually, having convenient buildings, situated about a mile apart from each other,—one purchased, the other built for the purpose, and both of them thoroughly adapted to the system of the schools.

Soon after the original schools had begun to prove their usefulness, it became clear to the managers that they were not accomplishing all that ought to be done, that there was still a portion of the neglected outcasts whom they were not reaching, and this forming the very class for whom the schools were originally intended—the little beggars and pilferers who infested the streets, and whom it had hitherto been impossible to draw to the schools.

It was resolved to make a bold and resolute assault upon this class, and to compel them to be ameliorated whether they or their parents wished it or not.

The Local Police Act for Aberdeen happily contained a clause giving power to put down begging. It provided for the punishment of beggars, but it did not devise any mode of caring for the beggar, whether old or young, or putting him in the way of supporting himself. It was passed before the enactment of the present Scottish Poor Law; it did one half of the work, it left the other half either not done or to be accomplished by voluntary enterprise.

This clause was employed in a way not perhaps intended by the Legislature, but still within the scope of the law, and which has proved most salutary to the community.

The intended proceeding was carefully explained to the authorities, and their support and assistance were judiciously given.

The managers of the Soup Kitchen gave the free use of their buildings, and this most important social and moral experiment was commenced with a sum of four pounds sterling, raised by subscription, not doubting that if good resulted the necessary funds would be furnished,—and so they have been.

On 19th May 1845, instructions were given to the City Police to lay hands on all the children found begging in the streets, and bring them to the Soup Kitchen, and in the course of the day 75 were collected, of whom only 4 could read.

The scene was one never to be forgotten by the few who witnessed it. Naturally alarmed at their capture, wholly ignorant of what fate might be awaiting them, they cursed and swore, kicked and fought and bit, but by firmness and kindness they were greatly subdued before night.

The most obnoxious part of the proceedings was the compulsory washing of hands and faces little accustomed to soap and water, and the only acceptable part was the ample supply of good food. *Teaching* could scarcely be said to commence on the first day, which was devoted to *training*.

Gradually during the day a certain amount of order was established: the boys began by degrees to understand what sort of place they had got into, that the treatment was not altogether to be condemned, that though the cold water might be a very unpleasant application, and the proposed lessons a very wearisome infliction, still the soup was very good and the bread very abundant; they had never had so much good food before, and it was worth enduring some discomfort to obtain. Some such reasoning seems to have passed through most of their minds in the course of the proceedings.

At eight o'clock they were dismissed; they were all invited to return next day, when they should have the same discipline and the same feeding, together with more regular teaching, and at the same time they were distinctly informed that they might come or not as they pleased, but that begging in any shape would not be tolerated; that their wants would be supplied as they had experienced in the school; that their choice now lay betwixt starving, or the prison, or the school, and they must make it for themselves.

Next day the greater part of the boys returned, and the managers felt that they had gained a great victory, and that a new and vast field of usefulness now lay before them. They entered vigorously upon it, and the school has been in active and useful operation down to the present day.

This school at once produced visible effects; the immediate removal of the whole of the troublesome boys who infested the streets made an unmistakeable change much to the advantage of all classes, and when it was necessary to raise funds for its support the working classes gave most gratifying testimony to their sense of its value.

The wealthier classes of the community subscribed £150, but the working classes, men and women depending on daily toil for daily bread, contributed no less than £250!—and when some of them were asked why they contributed thus liberally to support a school at which their own children would not be scholars, the reply was, "Before this school was opened we were afraid to trust our children a moment out of doors alone and unguarded, for they were exposed to learn, and did learn, all manner of mischief; but now the school has cleared the streets of the little vagabonds who corrupted them, and we are not afraid to let our own children out, and therefore we subscribe to the school."

This honest practical testimony to one good result, and that not the immediate object but the indirect effect, of the school, is invaluable, and at the time was felt to be most encouraging.

During the first year the total number of names placed on the roll was 159, of whom 18 were soon dismissed as unsuitable, 34 deserted, or were removed by their parents, 26 got into employment, 7 into other institutions, and at its close 74 remained on the roll, of whom 43 were boys and 31 were girls. Of these,

25	were from	3 to 7	years of age.
36	,, from	7 to 10	,,
11	,, from	10 to 13	,,
2	above........	13	,,

Thirty-four of those in attendance at the end of the year had been admitted during the first month, and of these, 2 could read, and 8 knew the letters at admission; and by the end of the year 23 could read tolerably, and 24 could read a little.

Their religious instruction had been utterly neglected; few of them had ever entered a church. Before the close of the year they were all in the practice of attending church accompanied by the teachers, and received careful religious instruction every day, but especially and very fully on Sunday evenings. The attendance became very regular, and, what was especially satisfactory, very few of the children were convicted of any offence. The good food procured the attendance, and the twelve hours spent in school left little opportunity to commit crime; thus commencing the abandonment of bad, and the formation of good *habits*, before any *principle* could be instilled.

The value of the work done was very small, but the police authorities most judiciously paid the salaries of the teachers, and the managers of the Soup Kitchen gave the use of their buildings without rent; so that the only outlay from the funds of the institution was for food, and for a partial supply of clothing, which was absolutely necessary. The average cost per head for the first year was £4.

This has proved the most valuable of all the schools; it at once attacked the evil at its fountain-head, and the fruits speedily appeared in the almost total cessation of street begging, and the gradual diminution of juvenile vagrants and offenders.

After a time the police authorities and the Soup Kitchen managers withdrew their support, and they acted wisely in so doing; the school has ever since been supported by voluntary contributions; its proper name is "The Juvenile School of Industry," but in Aberdeen it is best known, from its locality, as the Sugar House Lane School.

The number in attendance varies from 50 to 70 boys and as many girls.

The school-rooms are on different floors and most commodious; the only want is a play-ground, which from the situtation is unattainable.

Considerable difficulty was all along felt in confining the operations of the schools strictly to those children who required their aid, and excluding those whose parents or friends were able to maintain them at ordinary schools; and this was a most important matter, both in order to spare the funds of the schools and to satisfy the public mind.

To meet this difficulty the "Child's Asylum Committee" was invented and has been most successful. The duty is carefully to investigate every case in all its circumstances, and admit or reject, or hand over to some other institution, as may be found proper; in short, to interpose an effectual check betwixt the little mendicants and the school, in order to prevent what was not unlikely to happen,—a resort to street begging in order thereby to get at the good food of the school.

At first it met daily at 10 A.M.; but this soon became unnecessary, because there were not daily cases to examine, but it is still summoned whenever its services are required.

It was instituted in December 1846, and is a numerous committee, being composed of gentlemen who are either Magistrates of the City or Commissioners of Police, or Members of the Poor Law Boards of St. Nicholas and Old Machar, Directors of the House of Refuge, or Members of the Joint Committees of Management of the Boys' School and the Juvenile School; in short, of members of all the public bodies interested in the matter.

The inquiry is most searching into every circumstance which can guide in coming to a decision suited to the case, and its working has been most satisfactory; very few, almost none, have been admitted to the schools since 1846 who were improper objects; and it has not unfrequently happened that remonstrances and counsels given to parents had the happy effect of bringing them first to feel and then to undertake and discharge the duties they owed to their hitherto neglected offspring.

During the first five years this Committee investigated the cases of 700 destitute children, most of whom were admitted into one or other of the schools, and 198 of these were brought up to the Committee by the police.

The Ladies' Committee of the female schools make precisely similar inquiries into all the cases brought to their notice before admission.

The progress of the schools has been steady, and their good effects have become more and more visible every succeeding year, and have been demonstrated only more clearly by facts which at first seemed to militate against them.

One remarkable proof is derived from returns furnished by the rural police.

It was a well-known fact that children of very tender years were sent out by worthless parents to wander *alone* through the county to support themselves by begging and petty thefts, and that still greater numbers accompanied their parents to add force to their claims for charity, while a few were lent or hired for the same purpose to parties who had no suitable children of their own.

The constables of the rural police were instructed to return as correctly as possible the number of these children whom they encountered in their daily rounds. From the nature of the case the returns cannot be absolutely correct; but still they approximate to the truth, and the variations from year to year give information of much value.

The following is the Return for Ten Years.

Year.	Juveniles in company with Adults.	Juveniles alone.
41–42	272	57
42–43	370	77
43–44	302	60
44–45	302	65
45–46	250	14
46–47	211	6
47–48	225	6
48–49	239	1
49–50	260	2
50–51	170	4

Compare these returns with those already given from the prisons and from the industrial schools, and the result is as clear as figures can make it, that precisely as the schools are in vigorous operation or not, so the number of youthful vagrants diminishes or increases.

We have now had seven more years' experience, and the results are equally instructive though produced to some extent by circumstances which at the time were most unsatisfactory.

To bring these out we must again have recourse to the Prison and Police returns.

Commitments to Prison.

Year.	Committals to Aberdeen Prison.	Committals to County Prisons.	Total Committals.	Native of Town.	Native of County.	Total.
1852	23	1	24			
1853	24	1	25			
1854	47	2	49			
1855	34	3	37			
1856	34	9	43			
1857	31	9	40			
1858	12	3	15			

Juveniles apprehended.

Year.	Juveniles in company with Adults.	Juveniles alone.
1852	258	8
1853	585	21
1854	456	17
1855	416	8
1856	297	9
1857	199	1*
1858	169	4†

It will be observed that a very sudden and remarkable increase took place in 1853, 1854, and 1855, both of commitments of criminals and of juvenile vagrants met by the police. The school managers were completely perplexed and somewhat dismayed. Were the principles on which they had acted unsound? or had they failed to apply them aright? Was the great enterprise, hitherto so successful and a cause of so much thankfulness, after all to prove a delusion? They could not believe it, and yet the increase of offenders was

* City of Aberdeen. † Not one of these 4 belonged to the City or County of Aberdeen.

an undeniable fact. Many anxious meetings were held, and many searching inquiries were made, but for a long time they could only point to the ordinary producing causes of juvenile crime,—drunkenness of parents, parental neglect, cheap theatres and dancing saloons, and the facilities afforded by brokers' shops for the sale of small stolen articles; at last the active cause was discovered.

Rival institutions had been set up; schools attended by large numbers were in active operation, not to teach honesty and virtue, but to teach theft and crime; and at the same time to provide every facility for the disposal of stolen property, and to prevent the detection of the offenders.

Various wicked inducements were also held out to the unfortunate juveniles, tempting them in a manner utterly opposed to all good order and even decency, but which were not wanting in their results; they had their attractions, and they did their work.

From 1852 or 1853 to 1855 there were two if not more of these "schools for crime" attended by parties of from 12 or 14 up to 30 or 40.

This appalling discovery explained the whole mystery. Ultimately several of the teachers of crime were brought to trial, convicted, and their establishments broken up, and then the number of offenders speedily diminished, though, of course, time was required for the complete wearing out of the effects of such a nefarious system.

It is worthy of notice that these teachers of crime were tried and convicted of *theft*, or of *receiving stolen property*—not one of them for the infinitely more atrocious crime of teaching little children to be criminals.

There seems to be at present no law which can touch them for so doing, and yet there is scarcely a greater crime which man or woman can commit.

With this exception, which only proves in the strongest manner the value of Industrial Feeding Schools, the whole institutions have gone on and prospered, quietly doing their work, with those trifling alternations which occur in all children's schools, and which are of the greatest use in keeping the energies of managers and teachers in constant activity.

It would be useless to read, for no one could follow, statistical details exhibiting all the particulars of each school for each year, with the ages, parentage, and disposal of each child, but they are now produced for the information of those who choose to examine them; and they will be found full of interesting and instructive facts, all tending in one direction—to demonstrate that well-managed schools on the Aberdeen principles have, without doubt, solved the important question how the annual supply of juvenile criminals may be cut off at the fountain-head, and how multitudes hitherto allowed, if not constrained by the force of surrounding influences, to grow up into criminals, a torment to themselves and to society, may, by God's blessing, be transformed into self-supporting respectable members of society.

The first ten years of the schools saw them, after all their trials and vicissitudes, firmly established in Aberdeen, and not confined to it, but already extended to most parts of the country. The history of their introduction and progress elsewhere lies beyond the purpose of this paper.

The subject gradually took more and more hold of the public mind. The managers in Aberdeen early saw the importance of their schools receiving public sanction, and brought forward the subject in reports, memorials, and petitions, until at length it was taken up by the Legislature; and the stamp of the nation's approval of the system of Industrial Feeding Schools was indelibly fixed upon them by the passing of "Dunlop's" Act, on the 7th of August, 1854, applicable to Scotland only; and on the 10th of the same month, of "Palmerston's" Act, applicable to the whole of Great Britain.

These two statutes have introduced an entirely new principle, and in fact revolutionized the long recognized principles of our criminal law. They adapt and give legal sanction to the axiom that "Prevention is better than cure."

By Dunlop's Scotch Act, vagrant and neglected juveniles apparently under fourteen years, wandering about with no visible means of subsistence, may be sent by magistrates to a Reformatory or Industrial School, duly sanctioned by the Secretary of State, there to be trained and educated, but not to be detained, without their own consent, beyond the age of fifteen.

By Palmerston's British Act, magistrates are in like manner authorized to send juvenile offenders under sixteen to Reformatory Schools duly sanctioned by the Secretary of State, for not less than two, nor more than five years, but only after undergoing an imprisonment of not less than fourteen days.

Both statutes make provision for recovery of the cost of such young persons from the parties legally liable; both authorize grants of public money in aid of the schools, and both are entirely voluntary, or permissive, not obligatory. Magistrates may avail themselves of them or not as they think proper; and as the matter was new, and wholly untried as a legal proceeding, it was prudent thus to proceed. The time, if not yet arrived, must soon come, when no outcast children shall be sent to prison, but all sent to Reformatory Schools, there to be fed and taught and trained, without having the prison brand stamped upon them which is required by Lord Palmerston's Act,—a temporary concession to old and deep-rooted prejudices.

Under Dunlop's Act, if parties interested find security to the amount of £5 for the good conduct in future of any young person sent to school under the Act, then such young person is removed from the school and handed over to their care.

This clause is liable to considerable abuse, and ought ere long to be repealed: parties professing so much interest in these young persons ought to show it at an earlier period, and take proper care of them before they become either vagrants or criminals; and the nation ought not to allow those who have proved themselves so indifferent in the matter to interfere, and deprive the children of all the advantages of an Industrial School, without really offering anything certain and of equal value in return.

Those two statutes have already been productive of much good, and both magistrates and the public are daily becoming more willing to avail themselves of their provisions.

In order to have the benefit of the Palmerston Act for older convicted juveniles, a Reformatory has been erected near Aberdeen, mostly from the judicious application by the trustees of the late Dr. Watt, of part of the charitable funds left by him at their disposal. The building is plain, but most suitable for about fifty boys, with plans ready for its extension when required, standing on a farm of fifty acres, the property of the institution, and at present having between thirty and forty inmates. It has been only about two years in operation; and though all promises well, it is not yet time to look for results; only one or two, and these under peculiar circumstances, have as yet left the institution; the period of sentence of the first admitted has not yet expired. One satisfactory statement may with confidence be made, and that is that most of the inmates are thoroughly happy and contented in their abode, and this is one great step to their reformation.

Those who have from the first taken an active interest in the cause of neglected juveniles, can hardly realize to themselves the progress which has been made in less than twenty years.

In 1840 no special provision existed for their behoof; they had full permission to do what they pleased, and when they became troublesome to others, the prison, and perhaps the lash, were the only remedies applied.

In 1841 the first Aberdeen School of Industry was opened; the experiment went on and prospered; the example was followed; other towns opened similar schools; the system was found to do much good wherever it was tried. The public became more and more interested, for the good done was very perceptible, and the money-cost was very small; and as each town easily furnished a few zealous ladies and gentlemen to superintend the work, they were thankfully permitted to do so.

Then it became very evident that to punish criminals as of old was very costly, and rarely led to their reformation; but that to prevent crime was comparatively easy, and also far less costly.

These opinions gradually established themselves in the public mind, and from it of course took possession of the Legislature; and in about fourteen years from the opening of the first Industrial School, the Imperial Legislature passed the two leading statutes which firmly established them as fixed portions of our social system, and finally adopted the principle of endeavouring to prevent rather than to punish and reform.

Hitherto, of course, only partial and local results are seen; soon, greater and more extensive are to be expected.

What, then, are the principles on which these schools depend for success? They are so very simple that there is no small risk of their being overlooked in carrying out the actual working.

The schools supply what the children need, and what they cannot get for themselves—food, teaching, training; but they leave their energies free, they only seek to turn them from evil to good. Energy, activity, diligence need to be fostered in the young quite as much as their mental faculties, and any system of dealing with them which deadens these is fatal to future success. The want of men of eminence from among the tens of thousands who have been educated in poor-houses and hospitals, combined with the pre-eminence of men who have struggled in early life against every difficulty, prove the truth of this. It is no kindness to any one to deprive him of self-reliance, though it is often less troublesome than to enable him to depend on himself.

The Legislature has done well in the encouragement it has given to these schools, but it will be a fatal step if they try to do too much, and place them entirely on public support. It is absolutely necessary that a large amount of voluntary unpaid energy enter into the working out of the system.

There seems to be a social principle, not yet very much appreciated or understood, which makes it necessary that the best laws shall always be supplemented by private voluntary enterprise.

Let the law provide as it may for the poor, for the sick, for the criminal, there will always be found work just at the boundaries reached by the law which must be undertaken by the free-will enterprise of individual activity; otherwise there will be great blots and scars on the face of our social system, great evils without remedies; and this is in truth a vast blessing conferred by God on man, for it provides work equally advantageous to the rich and to the poor.

The principle which ought to govern all connected with the work of Industrial Schools is very extensive, but it is very simple,—earnest, hearty love of the outcast members of the human family viewed as immortal beings.

As the love of God to man is the source of all human happiness, so the love of men to one another is the great remedy for the social evils which afflict this earth.

The highest display of God's love to man is manifested in the great scheme of salvation through our Redeemer; and the best proof man can give of his love to his fellow-man, is to do whatever man can do to bring him to know and to receive the glad tidings as revealed in the Scriptures of Truth.

This is the plan which God himself has appointed; and every endeavour to reform men, not based on God's Word, and not guided by its precepts at every step, must fail of success.

It is a good thing, no doubt, for society that neglected outcasts should be reclaimed and trained up to be self-sustaining useful members of the community; but if the managers of Industrial Schools look no higher than to mere temporal results, they must in most cases fail to attain even what they desire.

The only well-grounded hope of success is to be found when the training to pass usefully and creditably through this world is based on, and made subservient to, the higher and holier training which communicates that knowledge which alone leads to life eternal.

Statistics illustrative of Progress of Aberdeen Industrial Schools.

Table of the Ages of the 69 Boys at Industrial School, 30th March, 1844.

Under	7	4	
Between	7 and 8	5	—— 9
„	8 and 9	11	
„	9 and 10	18	
„	10 and 11	11	
„	11 and 12	5	——45
„	12 and 13	10	
„	13 and 14	5	——15

Thus of the 69, 9 were under eight years of age, and 45 were from eight to twelve years old, and 15 from twelve to fourteen; 36 had lost their fathers; 4 only had lost their mothers.

1st April 1845, 72 Inmates.

Under	7	6	
Between	7 and 8	11	——17
„	8 and 9	7	
„	9 and 10	15	
„	10 and 11	11	
„	11 and 12	4	——37
„	12 and 13	8	
„	13 and 14	3	——11

Thus of the 72, 17 were under eight years, and 37 were from eight to twelve years old, and 11 from twelve to fourteen.

The fathers of 38 were dead, and eight more had deserted their families, making 46 in fact fatherless; two only were motherless.

Table of Ages of 91 Boys on Roll of Boys' School, 1st April, 1859.

Under	7 years	8	
Between	7 and 8	8	——16
„	8 and 9	20	
„	9 and 10	22	
„	10 and 11	13	
„	11 and 12	6	——61
„	12 and 13	6	
„	13 and 14	6	
„	14 and 15	2	——14

Thus of the 91, 16 were under eight years of age, and 61 were from eight to twelve.

34 have mothers; only 9 have fathers; only 48 have both parents alive; 8 have been deserted by fathers; 14 are illegitimate.

The comparison of these Tables for 1844, 1845, and 1859 shows that the schools are now attended by the same description of children as when they were first opened.

Table showing progress of Boys' School of Industry.

Year.	Average Attendance.	Average Total cost.	Food.	Earnings.	Net Cost.	Got employment directly from School.
		£ s. d.	£ s. d.	£ s. d.	£ s. d.	
1841–42	36	8 6 8	4 11 0	0 14 6	7 12 2	...
1842–43	52	6 8 0	4 10 4	1 2 8	5 5 4	...
1843–44	45	5 12 0	4 1 0	1 4 0	4 8 0	...
1844–45	52	6 0 0	4 0 0	1 10 0	4 10 0	17
1845–46	49	6 0 0	3 8 6	1 10 1	4 9 11	22
1846–47	66	5 17 10	3 14 0	1 16 4	4 1 6	14
1847–48	66	5 18 9	4 1 9	1 14 9	4 4 0	28
1848–49	64	5 10 7	3 15 7	1 7 6	4 3 1	18
1849–50	61	5 7 2	3 10 6	1 17 4	3 9 10	14
1850–51	64	4 18 5	3 1 3	1 14 4	3 4 1	7
1851–52	72	4 5 10	3 0 0	1 5 10	3 0 0	12
1852–53	66	3 11 5½	3 0 6	1 0 6	2 10 11½	8
1853–54	61	4 3 8½	3 0 6	1 1 1	3 2 7½	11
1854–55	53	4 7 9½	3 0 0	1 0 9	3 7 0½	14
1855–56	65	3 17 8½	3 4 8	0 15 3	3 1 7½	17
1856–57	53	3 10 11¾	3 0 1	1 0 8½	2 10 3½	15
1857–58	52	4 13 1	2 19 10¾	0 18 7	3 14 6	7
1858–59	77	4 7 9¾	3 0 7	0 16 0½	3 11 9¼	18

Table of Ages of Children at Juvenile School, Sugar House Lane, April 1846.—Number on Roll 73.

3 years of age	....	3	
4 "	....	10	
5 "	....	2	
6 "	....	10	—25 under 7
7 "	....	8	
8 "	....	7	
9 "	....	6	
10 "	....	15	—36 from 7 to 10
11 "	....	3	
12 "	....	1	
13 "	....	7	—11 from 10 to 13

2 were orphans; 5 had fathers only; 47 had mothers only; 20 had both parents alive; 2 only could read on admission; and 8 knew the letters of the alphabet.

Average expense about £4 a year; earnings very small.

Table of Ages of 132 Children in Juvenile School, on 1st April, 1859.

Under	5 years	....	8	
Between	5 and 6	....	12	
"	6 and 7	....	20	
"	7 and 8	....	27	—67

Between	8 and 9	16	
„	9 and 10	26	
„	10 and 11	7	
„	11 and 12	11	—60
„	12 and 13	4	
„	13 and 14	1	— 5

Thus of the 132, 67 are under eight years; 60 from eight to twelve; and only 5 above twelve years.

Of these 132, 6 have fathers only; 59 have mothers only; 64 have both parents; 3 are orphans; 19 have been deserted by fathers, and 32 are illegitimate.

Table showing Progress of the Juvenile School of Industry.

Year.	Average Attendance.	Average Total cost.			Food.			Earnings.		Net Cost.			Got Situations.
		£	s.	d.	£	s.	d.	s.	d.	£	s.	d.	
1845–46	57	4	7	8	3	7	4	8	5	3	19	3	26
1846–47	75	4	7	2	3	6	8	3	7	4	3	7	6
1847–48	84	5	7	4	3	2	0	4	0	5	3	4	15
1848–49	94	3	16	9	2	6	4	2	0	3	14	9	8
1849–50	85	4	0	0	2	2	10	2	10	3	17	2	10
1850–51	95	3	7	7	1	14	10	3	0	3	4	7	7
1851–52	94	4	2	3	2	1	3	6	9	3	15	6	12
1852–53	79	3	19	1	2	17	6	3	4	3	15	9	15
1853–54	73	4	3	10	3	8	9	7	4	3	16	6	11
1854–55	71	4	14	10	3	1	9	7	0	4	7	10	9
1855–56	79	4	6	4	3	6	5	4	3	4	2	1	8
1856–57	73	4	8	10	3	0	7	5	10½	4	2	1½	15
1857–58	81	4	6	4	2	12	9	4	5½	4	1	10½	9
1858–59	120	3	3	2	2	1	11	2	10½	3	0	3½	12

N.B. The higher earnings of the years 1846, 1854, and 1855 arose from the boys being on the whole somewhat above the average age.

The last column shows only those who have obtained situations direct from the school.

Table of Ages of Girls at Female School, December 1845.—Number on Roll 64.

Under	7 years	2	
Between	7 and 8	11	—13
„	8 and 9	10	
„	9 and 10	12	
„	10 and 11	13	
„	11 and 12	8	
„	12 and 13	6	
Above	13	2	—51

Thus 13 were under eight years of age, and 51 from eight to thirteen; 30 had both parents alive; 5 had fathers only; 26 had mothers only; and 3 were orphans.

December 1846.—60 on Roll.

Under	7 years	2	
Between	7 and 9	26	
„	9 and 11	22	
„	11 and 14	10	—60

Thus 2 were under seven, while 48 were from seven to eleven years; 25 had both parents alive; 24 had mothers only; 7 had fathers only; 4 were orphans; and of the 25 who had both parents alive, 6 had been deserted by fathers,—making 30 dependent on mothers only.

	£	s.	d.
Total cost of each pupil	3	18	$10\frac{3}{4}$
Earnings „	0	6	$11\frac{1}{2}$
Net cost „	3	11	$11\frac{1}{4}$

In 1846 the school was divided into two, viz. Sheriff Watson's Female School of Industry, and the Aberdeen Female School of Industry.

Sheriff Watson's Female School in 1851 had 71 on the Roll, of whom 58 were under eleven years of age, and the cost per head £2 8*s.* 6*d.* per annum. In 1858–59 the average number on roll was $63\frac{1}{2}$, while the average attendance on week days was 61,—a result rarely attained in any school. The average attendance on Sunday was $55\frac{5}{12}$.

Ages of 70 on Roll, 1st April, 1859.

Ages.		Time at School.	
Under 8 years	8	Under 1 year	34
„ 9 „	18	„ 2 „	16
„ 10 „	17	„ 3 „	10
„ 11 „	13	„ 4 „	4
„ 12 „	9	„ 5 „	4
„ 13 „	4	„ 6 „	2
„ 14 „	1		

Of these 70, 36 have both parents alive, and of these 12 have been deserted by fathers; 1 by her mother; and 1 by both parents; 27 have mothers only alive; and 1 is an orphan.

27 left during the year; 8 required at home, 7 to domestic service, 4 parents leaving Aberdeen, 2 in bad health, 3 to manufactories, 2 improved circumstances of family, and 1 to Orphan Institution.

	£	s.	d.
The cost per head for food was	2	7	$7\frac{1}{2}$
The total cost per head	3	18	$5\frac{1}{2}$
The earnings per head	0	2	$4\frac{1}{2}$
Net cost	3	16	1

Aberdeen Female School of Industry.

In 1851 the number on roll was 77, of whom 63 were under twelve years of age; 18 obtained situations as domestic servants during the year; and the average expense of each was £3 8*s.* per annum.

In 1856 the number on roll was 81, of whom 59 were under twelve years of age. During the year 14 went to domestic service and 5 to other work, and the full number on the roll was usually present at school.

3 were orphans; 2 deserted by fathers; 20 had mothers only; 23 both parents alive; and 18 illegitimate.

In 1859 the number on roll was 96, of whom 53 were under ten years of age; 36 from ten to twelve; and 7 from twelve to fourteen.

24 obtained domestic service, and 7 other employment.

1 was an orphan; 8 deserted by fathers; 34 fathers dead; 9 mothers dead; 3 mothers dead and deserted by fathers; 1 deserted by both parents; 25 both parents alive; and 15 illegitimate.

Average cost of each child per annum £4 7*s.* $11\frac{3}{4}$*d.*

Average attendance 93.

Proceedings of Child's Asylum, opened December 1846.

	Boys.	Girls.	Total.
Dec. 1846 to Dec. 1847 police brought up	56	39	95
„ 1847 „ 1848 „	30	16	46
„ 1848 „ 1849 „	22	6	28
„ 1849 „ 1850 „	10	2	12
„ 1850 „ 1851 „	11	6	17

Making in five years 129 boys and 69 girls,—in all 198.

It soon became apparent that the operations of police were so effective, that they must soon cease to supply sufficient numbers of pupils to the schools, and the Child's Asylum Committee resolved to receive and investigate applications from the parents or friends of neglected juveniles.

The first four years of this mode of proceeding gave the following results:

	Boys.	Girls.	Total.
1848. Applications on behalf of	92	57	149
1849. „ „	103	32	135
1850. „ „	82	30	112
1851. „ „	88	21	109

The general result of the first five years' operations of the asylum is that 703 cases of neglected children were investigated by means of it, most of whom were sent to one or other of the industrial schools; *e. g.* in 1851, of the 109, 54 boys were sent to the boys' school; 42 boys and girls to the juvenile school; 2 to Inspector of Poor; and 10 refused as unsuitable.

The Child's Asylum continues in constant operation, and a full record is made and preserved of each case; but no reports or tables have been printed since 1851.

On the Upper Silurians of Lesmahagow, Lanarkshire.

THE interest excited at the Glasgow Meeting, in 1855, by the announcement of a highly fossiliferous tract of Upper Silurian strata in the parish of Lesmahagow, and by the exhibition of their new and rare fossil forms at the Leeds Meeting in 1858, induced the Association to vote the sum of £20 towards the further exploration of these beds by their original discoverer, Mr. Robert Slimon. This sum was placed under the direction of a Committee consisting of Sir Roderick I. Murchison, Mr. Page, and Professor Ramsay; and under the condition that the specimens should be given in the first place to the public Museum of Edinburgh, and duplicates thereafter to the Museums of Economic Geology in London and Dublin. In terms of this grant, the Committee, through their resident member, Mr. Page, have now to report:—

That during the past summer Mr. Slimon and his son have shown great industry in exploring the various sections exhibited in the channels of the Logan, Nethan, Priesthall Burn, and other streams that flow from the Nitberry Hills, and cut through the strata in question. As these strata consist for the most part of brittle slaty mudstones, wholly unfit for any economic purpose, and rendered still more brittle by the intersection of numerous felspathic dykes, there was no other mode of exploration than by quarrying directly for the fossils, and this at as many points as were accessible, and as far as the limits of the grant would allow.

The result of these operations have been to exhibit still further the highly fossiliferous character of the Nitberry Silurians, and to give ample indication of a very varied and curious crustacean fauna altogether new to Palæontology. Molluscous remains of well-known Upper Silurian genera have also been obtained in sufficient numbers to prove the affinities of the beds; and indications of both an aquatic and terrestrial flora seem by no means rare throughout the strata.

Another fact fully established by the exploration is, that while the lower beds exhibit the closest palæontological relations with the Ludlow beds of England, the upper pass insensibly—and without any marked boundary, lithological or palæontological—into flaggy tilestones which are the undoubted equivalents of the lowermost Old Red of Forfarshire.

The specimens obtained during the explorations have a threefold value:—1st, as proving the true Upper Silurian epoch of the Nitberry strata, and thus affording a clue to the investigation of other Sub-Devonian tracts in Scotland which are yet but imperfectly understood; 2nd, as adding new forms to the life of a former epoch, and thus extending the boundaries of our zoological knowledge; and 3rdly, as enabling the Government palæontologists, who have recently published their first monograph on the Eurypteridæ, to understand more clearly the nature of this curious family of Crustaceans, and to correct what must now evidently appear as misinterpretations of their structure and affinities.

Arranging in order the fossils obtained by Mr. Slimon, we have of

Plant Remains:—

Numerous fucoidal impressions.
Calciphytes.
Lepidendroid stems evidently in fructification.

Mollusca:—

Modiolopsis, 2 species.
Platyschismus, or Trochus helicites.
Nucula.
Lingula cornea.
Orthoceras.
Pterinea.
Avicula.

Annellida:—Spirorbis Lewisii.

Crustacea:—

Fam. Eurypteridæ.
Pterygotus bilobus.
„ peronatus.
„ punctatus.
„ acuminatus.
Eurypterus lanceolatus.
„ pygmæus (?).
Stylonurus spinipes, and another.

Fam. Nebaliadæ:—
Ceratiocaris, several undetermined species.

Fam. Limnadiadæ:—
Beyrichia.

Undetermined organisms, apparently Crustacean or Amorphozoan.

In none of the beds examined, nor during the whole of Mr. Slimon's previous explorations, which have extended over several years, has there ever been detected any trace of an ichthyolite—fish-scale, fin-spine, or tooth—a noticeable fact, considering the highly fossiliferous character of the strata, and the indications that many of them give of littoral as well as of deep-sea conditions of deposit.

Looking at the palæontological value of Mr. Slimon's discoveries, and the additional interest they have conferred on Palæozoic Geology, your Committee would respectfully urge upon him a continuance of his labours, conjoined with the hope that, if at all compatible with the other requirements of the Association, a further grant of say £10 or £20 should be made to assist in so desirable an object.

Report on the Results obtained by the Mechanico-Chemical Examination of Rocks and Minerals. By Alphonse Gages, *M.R.I.A., Curator of the Museum of Irish Industry.*

I had the honour of bringing before the Section at the last meeting of the Association at Leeds, a short paper entitled "On a Method of observation applied to the study of Metamorphic Rocks, and on some Molecular Changes exhibited by the action of Acids upon them." The principal feature of this method of examination consisted in exposing thin plates of rocks, or crystals cut in certain directions, to the slow action of solutions of acids or alkalies of different degrees of concentration, under such varied circumstances as the special characters of each rock may suggest. The general result of this action was the gradual removal of some or of all the bases, a residue being left, the structure and composition of which indicated the mode of formation of the original rock.

The idea of submitting rocks or minerals to the action of various solvents is not new. But hitherto experimenters have operated upon the powdered mineral. I operate upon fragments which exhibit not only the *chemical* constitution of the substance under examination, but what is in many instances of still greater importance, the *mechanical* constitution also. An example will explain still better the difference.

If we powder a piece of alum and put it into water, it will dissolve, and so far as the appearance presented by the powdered mass, uniformly. But if we take the same piece of alum, and instead of breaking it up, grind a flat surface upon it, and place it, as Daniel did, in water with its polished face downwards, the water will act upon that face very unequally; after a time crystals will stand out in relief, and what looked like a homogeneous crystalline mass, will be shown to be made up of a confused mass of interlaced crystals cemented together.

Observers have no doubt dissolved minerals in fragments as well as in powder, but they have not, so far as I am aware, done so with the object of studying the peculiar mechanical arrangement of the components of rocks, and certainly have not done so as a methodical system of examination.

If, as Daniel's experiments show, we may learn much regarding the molecular structure of even a crystalline mass of a homogeneous substance by the manner of dissolving it, how much more so must this be the case with such complex mechanical mixtures as most rocks are! Before detailing the experiments which I have made during the past year, I may observe, that although the application of this method of examination (which, for want of a better word, we may call mechanico-chemical) is limited to a certain number of rocks, it may be advantageously employed as a kind of preliminary qualitative analysis, in the case of the majority of sedimentary rocks, whether metamorphic or otherwise, before reducing them to powder, in order to analyse them by the ordinary method. The slow and prolonged action of acids on minerals or rocks composed of a mixture of minerals, or even those mainly composed apparently of one mineral, enables us sometimes to discover substances which would otherwise have passed unnoticed, and the constituents of which would consequently be confounded with those of the rest of the rock.

The number of rocks which resist without decomposition the prolonged action of acids such as HCl and HO SO_3 at various temperatures, up to their boiling-point, is extremely limited; and this is especially the case if fragments of rocks be subjected to the alternate action of the two acids. Those especially which have undergone a slight alteration, such as the commencement of the formation of hydrated minerals, always yield to such treatment.

A great number of rocks, consisting of aluminous silicates or silicates of lime or magnesia, frequently leave, after treatment with acids, skeletons which show us the manner in which many minerals may have been decomposed, the residues which they left often serving as the basis of new formations. In examining calcareous rocks containing such skeletons, it is necessary to use dilute acid solutions, sometimes indeed extremely so; as concentrated acids might in many instances decompose the skeletons, especially if they appeared to contain hydrated silicates.

The rocks which I have submitted to examination since the last meeting of the Association may be classified as follows:—

1. Comparative examination of the residues of Permian magnesian limestones from ten localities.

2. Comparative examination of the magnesian limestone of Howth, Co. of Dublin, contrasted with those of the Permian localities.

3. Magnesian limestone conglomerate from Downhill, Co. Londonderry.

4. Examination and analysis of a pseudo-dolomite, found at the junction of the trap and carboniferous limestone, at Stone Park Quarry, $2\frac{1}{2}$ miles north of Six Mile Bridge, Co. of Limerick.

5. Experiments on the composition and structure of the residues obtained from the Calp or middle limestone, Co. of Dublin, and of the lower limestone shales of Drogheda.

6. On chloritic slate, and metamorphic limestone derived from it.

7. On a metamorphic limestone containing garnets reposing on the granite near Gweedore River, Co. Donegal.

1. *Magnesian Limestones from Permian Localities.*—There appears to me to be considerable confusion in the minds of some geologists regarding what are called Magnesian Limestones. The terms Dolomite and Magnesian Limestone, in the sense in which they are sometimes employed, seem to imply a similarity in the mode of formation. This is, however, far from being the case. Most limestone rocks, whatever may be their origin, contain some magnesia; and even recent corals and marine shells have been found by the investigations of Dana and Forchammer to contain some.

I have no intention to propose a nomenclature of magnesian limestones; I merely wish to trace the distinctive characters of some of those rocks by means of the residues which they leave when treated with acids, and which are often the only witnesses which could instruct us as to the mode of their formation. Some of these residues are very characteristic; thus the Permian are ochrey, and always contain fragments of hyaline quartz, sometimes rounded on the angles. Those, on the contrary, derived from magnesian limestones formed either by infiltration or in a tranquil medium, and

Tabulated Statement of the Characteristics of the Permian Magnesian Limestones examined, and the Proportions of Residues which they contain.

No.	Locality.	Description of Rock.	Relative proportion of Residue and Carbonate in the Rock.		Observations.
			Soluble matter consisting chiefly of Carb. of Lime and Magnesia.	Residue.	
1.	Townland of Templereagh.	Variegated purplish and buff-coloured magnesian limestone breaking with a sharp angular fracture.	90·70	9·30	Residue of a highly plastic ochrey clay of a yellowish buff-colour, and containing a fine debris of transparent quartz.
2.	Templereagh.	Magnesian limestone, purplish grey, exhibiting over its surface small shining grains of quartz.	71·65	28·35	Residue consisting of a ferruginous clay of a violet-red colour, intermingled with about its own weight of debris of quartz.
3.	Artrea, Co. Tyrone.	Magnesian limestone of a light buff-colour and oolitic structure.	91·30	8·70	Residue composed chiefly of very small fragments of transparent quartz, with some opalescent ones also, as large as a pea. Traces of yellow ochre.
4.	Yorkshire.	Kidney-shaped nodules of magnesian limestone, of a liver-colour: fracture highly crystalline.	98·72	1·28	Yellowish-brown clay and minute fragments of transparent quartz.
5.	Durham.	Stalagmitic concretions of magnesian limestone of a light-brown colour.	98·34	1·66	Light-brown ochre, with some fragments of hyaline quartz.
6.	Durham.	Fine-grained cellular magnesian limestone of a whitish-grey colour.	98·70	1·30	Very minute granular fragments of quartz, with a light brown-coloured ochre.
7.	From the same locality as No. 6.	Characters of the rock the same as the preceding.	98·10	1·20	Very minute grains of quartz, with light-brown ochre.
8.	Cheltenham.	Light brown-coloured pisolitic magnesian limestone.	94·45	5·55	Light-brown ochre, with small angular fragments of hyaline quartz.
9.	Sutton near Ashby, N.W. Manchester.	Red earthy compact magnesian limestone.	78·00	22·00	Red ochre, with some fine hyaline quartz sand.
10.	Exhall, Coventry.	Sandstone formed of fine quartz sand cemented by carbonate of lime and magnesia.	21·53	78·47	If we reverse the numbers representing the sand and carbonates, we shall have a magnesian limestone of the same character as No. 9.

under the influence of the decomposition of other rocks, contain, in the majority of cases, crystalline substances in a whole state, or partially decomposed silicates.

Having just indicated the comparative distinctive characters of the residues left by the magnesian limestones of different kinds, I will now proceed to describe those of the Permian in detail.

The magnesian limestones of the Permian group which I have had an opportunity of examining, leave, when treated with hydrochloric acid, more or less abundant residues, offering the same lithological characters. These residues are ferruginous clay, varying in colour from deep red to very pale yellow. These variations of colour are due to the relative proportions of sesquioxide of iron present, and sometimes to that of manganese also. The residues contained besides fragments of transparent quartz, which may be separated by washing. The oolitic characters which some of those magnesian limestones assume are always due to those fragments of quartz, which serve as nuclei around which the deposit of carbonates is formed. The quantity of residue sometimes exceeds 30 per cent., and often does not amount to ½ per cent.; but whatever may be the quantity of the residue, its lithological characters remain always the same.

The following Table contains the results of my examination of each of the specimens of magnesian limestone from Permian localities.

No. 3 in the Table illustrates very strikingly the origin of the oolitic structure in calcareous rocks. When a fragment was exposed for a short time to the action of hydrochloric acid, so as to remove part of the lime, the grains of sand were observed standing in a kind of hollow shell. It differs, however, from the generality of oolitic rocks, in which the grain of sand or matter forming the nucleus is surrounded by concentric layers of calcareous matter. In the rock under notice, the grains of sand appear, so far as can be judged by means of a lens, to have been simply imbedded in the cementing parts.

2. *Howth Dolomite.*—The dolomite of Howth, Co. of Dublin, belongs to the carboniferous series, and rests on Cambrian slates. It is of a light yellowish-brown colour and has a compact crystalline texture, with many cavities, however, which are filled with well-developed crystals of bitter-spar. When examined with a lens, it appeared to be formed of a series of irregular serrated layers, sometimes containing oxide of manganese in more or less quantity. On being treated with acetic acid, it divided itself into small granular crystals of bitter-spar, resembling an extremely fine sand. It thus presented all the characteristics of true dolomite.

Treated with dilute hydrochloric acid, it left a residue never exceeding 3 per cent., and consisting of a reddish-brown ochrey clay mingled with crystals of quartz, which were separated by agitating the residue in water. They consisted of very fine acicular crystals of opake quartz, having a fibrous arrangement, the edges of some of the crystals being somewhat eaten away. Washed several times with hydrochloric acid, and then treated with hydrofluoric acid, these crystals yielded an appreciable quantity of alumina, oxide of iron, lime, and magnesia, a circumstance which suggests that they may be the relics of some augitic or hornblendic rock. The Rev. Prof. Haughton, to whom I submitted these crystals, and who examined them, considered them to be "fibrous quartz, and such as occurs in the minute veins of quartz in the slate rocks of which the Hill of Howth is formed." What is most remarkable in connexion with those crystals, is the constancy with which the residue is found disseminated throughout the whole dolomitic mass of Howth.

The composition in 100 parts of the Howth dolomite may be thus represented as follows:—

Carbonate of lime	53·897
Carbonate of magnesia	43·610
Protoxide of iron	1·403
Residue { Ochrey clay	0·735
Residue { Fibrous quartz	0·196
Peroxide of manganese (in variable quantity).	
	99·841

3. *Magnesian Conglomerate from Downhill, Co. Londonderry.*—This rock, which has been improperly called hydrocarbonate of magnesia, is formed of spherical nodules encircled by a greenish paste, composed generally of carbonate of iron and of a partially decomposed ferro-magnesian silicate.

The composition of the part of this conglomerate soluble in dilute hydrochloric acid varies very much, as does that of the residue likewise. It sometimes acquires the character of true dolomite; and, according to Prof. Oldham, it contains crystals of bitter-spar disseminated through the mass. The following Table, containing the results of two analyses of the soluble part, will show the character of the variation alluded to:—

	I.		II.	
Carbonate of lime	63·700		70·863	
Carbonate of magnesia	21·325		17·481	
Protoxide of iron	3·400		1·111	
Residue	8·875		0·896	
Water	2·700	(by difference)	9·600	(experimentally).
	100·000		99·951	

The following results, obtained by Dr. Apjohn, bear out what has been said above, that the proportion of magnesia to lime sometimes reaches that observed in true dolomite:—

Carbonate of lime	54·88
Carbonate of magnesia	38·23
Carbonate of iron	5·93
Silex and loss	0·96
	100·00

The residue left after the dissolution of the carbonates in dilute hydrochloric acid, is generally of a variable greenish colour and a spongy texture; it contains a quantity of water, and also some organic matters.

The following Table gives the results of analyses of three specimens of this residue:—

	I.	II.	III.
Silica	40·371	60·725	70·532
Magnesia	13·719	5·656	4·259
Lime	——	0·251	——
Protoxide of iron	6·913	5·461	5·218
Alumina	0·216	2·557	0·473
Water and organic matter, &c. by difference	38·781	25·350	19·518
	100·000	100·000	100·000

In examining one of those residues with a lens, I found a perfect octahedron of red oxide of copper.

4. *Pseudo-dolomite.*—This rock was found, according to Mr. O'Kelly of the Irish Geological Survey, at the junction of the trap and carboniferous limestone at Stone Park, 2½ miles north of Six Mile Bridge, Co. of Limerick. It presents the appearance, at first sight, of the dolomitic limestone of Howth and other carboniferous localities; and is of a brown colour passing into yellow, being traversed by a great number of fine veins of calcite. It is covered by an ochrey substance, similar to that which results from the decomposition of the trap. It left, after digestion with dilute hydrochloric acid, a residue preserving the form of the piece of rock; it had, however, so little cohesion, that it separated into grains on the slightest agitation.

The composition of this rock may be represented thus:—

Carbonate of lime	57·620
Carbonate of magnesia	5·892
Carbonate of iron	7·590
Alumina	0·590
Water	2·820
Felspathic residue	25·780
	100·292

The residue, when washed and dried, exhibits under the microscope cellular fragments of an apple-green colour, analogous to some residues derived from the decomposition of felstones and greenstones. With this substance were also found grains of hyaline quartz.

This residue is attacked by boiling sulphuric acid, which leaves the quartz debris untouched. Analysed in this way the following results were obtained:—

Silica and fragments of quartz	73·491
Alumina	9·467
Fe_2O_3	4·127
Lime	0·552
Magnesia	traces
Potash	4·277
Soda	1·451
Water	6·502
	99·867

It results from this analysis, that the residue is a felspathic mass, disintegrated by some mechanical means before it became enveloped by the calcareous matter which forms the existing rock. Unless this were so, the quartz could not be found in a fragmentary condition.

If the rocks which formed the subject of the preceding observations were analysed in the ordinary way, by crushing them to powder, all the evidence regarding their origin and probable mode of formation, which has been so well exhibited by slowly operating with acids upon fragments, in such a manner as not to break up or alter the foreign substances enclosed by the carbonates, would have been obliterated. Where dolomitic rocks are associated with basalt and other igneous rocks, and enclose silicated minerals, such as tourmaline, tremolite, &c., which are characteristic of igneous rocks, geologists are able to recognize at once the connexion between the dolomites and the igneous rocks; but in very many cases dolomitic rocks bear no such visible evidence of relationship to other rocks, and yet many have been formed by their metamorphosis. The long list of constituents, such as alumina, protoxide of iron, silica, &c., which is given in the Tables representing the analyses of limestones and dolomites, conveys but little information as to how they came there. On the other hand, by studying the nature of the residue left by the magnesian limestone of the Permian formation, we have evidence that they were formed by single deposition. Again, the residue of delicate fibrous quartz which is found in the Howth dolomite, if not characteristic, is at least indicative of change subsequent to its deposition, a conclusion strongly supported by the cellular structure of the rock, which, according to Elie de Beaumont and Morlot, affords incontestable proof of alteration subsequent to the deposition of calcareous rocks. The dolomitic conglomerate of Down Hill and the pseudo-dolomite belong to a different class of phenomena. In the former case we have a species of conglomerate formed of chalk and decomposing amygdaloidal basalt. The calcareous part became more or less dolomitic, crystals of bitter-spar being sometimes formed; the magnesia forming the essential part of the residue is evidently the source of alteration, and accordingly varies, as is seen in the Table, and sometimes even wholly disappears. The protoxide of iron also is gradually removed along with the magnesia, and so completely sometimes that only a siliceous skeleton remains. The previous analyses of the mass give us no clue whatever to this mode of formation, and indeed do not afford any evidence whatever of the difference between it and any other kind of dolomite. The character of the residue fully explains the history of the pseudo-dolomite. It consists of the relics of some felspathic rock enveloped in a mass of carbonate of lime, magnesia, and iron, themselves the products of decomposition of local trappean rocks. So far as the individual rocks examined are concerned, the results are of course new; but the formation of dolomites of the character just described has been long since known and their relationship to igneous rocks clearly indicated; I do not therefore bring forward the preceding examples because they contain any general fact hitherto unknown, but because they serve to illustrate the true method which should be followed in the analysis of rocks. To complete the illustration, it would be necessary to contrast the results obtained by means of it, with the many elaborate tables of analyses annually published, and which, so far as the explanation of geological phenomena is concerned, are wholly valueless, however admirable they may be as specimens of skill of the analysts in separating different substances from one another.

5. *Calp and Lower Limestone Shales.*—The mountain limestone dissolves in acids without leaving any earthy residue; and when the solution is filtered, only a little charcoal remains on the filter. But when portions of the intermediate rocks are treated with acid, they leave residues more or less abundant, consisting of sand, clay, or carbonaceous matter and iron pyrites. These residues, disseminated through limestones, completely alter their lithological appearance, and communicate to them different physical properties; in this way are formed the various limestone-shales, grits, &c. of the carboniferous formation. These calcareous substances, when digested for a longer or shorter period according to circumstances, in water slightly acidified by hydrochloric acid, are easily penetrated in the cold, and the whole of the carbonate of lime is dissolved out. The skeletons which these different deposits leave on being thus treated, indicate very clearly, as in the case of the Permian magnesian limestones, some of the conditions under which the rocks have been formed.

A specimen of hydraulic limestone from the environs of Milltown, Co. of Dublin, treated in the manner just described, gave—

Carbonate of lime	76·20
Carbonate of magnesia	traces
Clay	8·30
Sand	14·65
Carbonaceous matter, pyrites and amorphous sulphide of iron	0·50
	99·65

This limestone, which is very hard and has a conchoidal fracture, owes the physical properties which distinguish it to the sandy residue forming its skeleton. The latter retains the external form and appearance of the original rock; and even fossil-casts may be recognized and determined. If the skeleton be ignited, the carbonaceous matter is burned away, leaving the cast of the fossil perfect. The skeleton thus exposed represents the sand of the original sea-bottom prior to its infiltration with calcareous matter.

When the quantity of argillaceous matter equals that of the carbonate of lime, and especially when the carbonaceous matter is present in a considerable quantity, this calcareous residue presents all the character of a true mud. This is the case with the lower limestone shales from the neighbourhood of Drogheda, which may be represented by the following composition:—

Carbonate of lime with carbonate of magnesia	47·10
Residue of clay and sand containing iron pyrites	47·75
Carbonaceous matter	5·15
	100·00

This residue, and indeed all the similar beds belonging to that formation, contain a good deal of iron pyrites and sulphide of iron in what may be called an amorphous state—apparently a proto-sulphide, as it evolved sulphuretted hydrogen on being treated with acids; both these are included in the clay and sand, and partly in the carbonaceous matter.

I may here observe that the quantity of residue, and of carbonaceous matter, varies in different parts of the rock from the same quarry. Thus a specimen taken at a short distance from the locality of the last specimen had the following composition:—

Carbonate of lime with carbonate of magnesia		55·40
Residue	Clay and sand with pyrites	36·00
	Carbonaceous matter	8·60
		100·00

In some of these consolidated muds the lime is almost wholly absent; the lithological character of the residues, however, remains constant. The sand separated from the clay is extremely fine when observed under a strong lens. The analysis of some of these residues may perhaps serve to trace the source from which they were derived.

I have already alluded to the existence of two compounds of iron with sulphur in these beds; and I may here remark that the characters which the lower limestone shales, as for instance that of Drogheda, present, appear to offer an explanation of the circumstances under which these sulphides were formed. We are daily witnesses of the fact, that under the influence of water and organic matter, and exclusion of air, sulphates dissolved in water are reduced to the state of sulphides, which convert the salts of iron in contact with them into sulphide. The sulphide thus formed is amorphous, as may be observed in the black mud which is found under the pavement of streets, and which evolves sulphuretted hydrogen. Now the mud from which these limestone shales have been formed, was one in which animal and vegetable substances abounded; for they are full of fossils, and the carbonaceous matter is derived from their decay. I may add that many of these fossils are entirely covered by pyrites.

The formation of bisulphide of iron appears to require an excess of sulphur, and would naturally be most readily formed wherever there was an excess of animal organic matter,—a supposition which is supported by the fact recorded by Mr. Pepys*, and cited by Sir Charles Lyell in his 'Manual of Elementary Geology.' It must be admitted, however, that iron pyrites is found in other rocks belonging to the carboniferous formations almost or wholly free from organic matter. The existence of crystals of iron pyrites in granite and trap rocks under circumstances where it would be difficult, if not impossible, for organic matter to intervene, show that that mineral may be formed in various ways.

It is worth while remarking, however, that crystalline sulphur has been frequently found in mountain limestone, in which there is not much organic matter.

Had iron been abundant in the neighbourhood, this sulphur would doubtless have been converted into pyrites.

6. *Chloritic Slate and supposed Metamorphic Limestone derived from it.*— The ordinary mode of analysing rocks gives no assistance whatever in determining the origin of rocks metamorphosed by igneous agency; it does not even enable us to determine positively whether a rock has been metamorphosed by heat or not. The remaining experiments which I have to describe were made with rocks which are generally assigned to this class, and which therefore afford examples of the advantages which may be derived from the employment of the method of examination which I have pursued. The rocks which formed the subject of experiment were, a specimen of altered chloritic slate, and two specimens of what is usually considered as metamorphic limestone. Beds of this class are found in the N.W. of Ireland, sometimes resting on granite, and always associated with such rocks as gneiss, mica-schist, hornblende slate, &c. I think I have established an interesting relationship between one of those beds and a chloritic schistose rock, which, if it be not wholly opposed to the igneous metamorphosis of the calcareous rock, undoubtedly proves that it could not have been subjected to a very high temperature.

Before describing the calcareous rock alluded to, it is necessary to give an account of the chlorite schist, and the results of my analysis of it. The rock, which contains some crystals of augite or hornblende and magnetic iron, occurs in the Townland of Cavan Lower, half a mile east of the town of Stranorlar in the Co. of Donegal. It effervesces with acids, as most rocks of a similar character do; and when digested with them, the micaceous part is partially attacked. On being boiled for some time with acids, the chief part of the chloritic and other minerals separate from the quartz. Here an important problem suggested itself, namely, in what state did the quartz exist? Was it formed in the rock by the action of the heat, that is, did the original rock separate under the influence of heat into chlorite and quartz? or was it originally composed of quartz and some other substance, which alone changed into chlorite? With the view of attempting a solution of this problem, which applies equally to most kinds of schistose rocks, some thin plates of the schist, carefully detached from different parts of the rock, were treated by diluted hydrochloric acid until every thing soluble was dissolved out. The plates were then repeatedly submitted for some time to the successive action of

* Geological Transactions, vol. i. p. 399, First Series.

boiling hydrochloric and sulphuric acid, care being taken, however, to avoid a rapid ebullition, in order not to break or deform them. This treatment was continued until almost every thing soluble in acids was removed. There then remained a residue of beautiful hyaline quartz fragments enveloped in semi-transparent nacreous crystalline-looking scales. These scales being the siliceous skeletons left by the foliated chlorite, they dissolved in caustic potash; so that after a few successive treatments with acids and caustic potash there only remained quartz debris, some of the grains still bearing the impression of the mineral substances which had adhered to them. Before treating the siliceous residue with caustic potash, the nacreous scales and quartz were so intimately mingled, that at first sight it would be difficult to say whether the latter occurred as fragments, or in an unaltered crystalline state. Treatment with caustic potash removes all doubt, however, on this subject.

The following are the results of an analysis of the chloritic slate:—

Alkalies (potash)	0·545
Magnesia	5·439
Lime	0·965
Protoxide of iron and a little sesquioxide of iron derived from the magnetic oxide	9·064
Alumina	7·360
Silica and quartz	61·762
Water	2·862
Carbonate of lime	11·081
Carbonate of magnesia	1·024
	100·102

The ratio of the oxygen in the protoxide bases existing as silicates in this chloritic slate is to that in the alumina as 4·464 : 3·440, that is, there are four equivalents of protoxide bases to one of alumina, which is exactly that in typical chlorite of the formula $4(RO, SiO_2)\ Al_2O_3, SiO_2+3HO$. The water in the slate, however, would only correspond to two equivalents; but, on the other hand, the quantity of water in chlorite is subject to vary, and some analyses have been recorded in which the water does not exceed two equivalents.

The carbonate of lime or magnesia has no doubt been formed by the decomposition of augite or hornblende. From this it would appear that the original material out of which the chloritic slate was formed, consisted of a calcareo-magnesian slate-clay or shale intermixed with hyaline quartz debris, that is, a rock resembling in composition rich clay marls.

Having thus ascertained, with considerable probability of truth, the origin of the chlorite, I shall now endeavour to show that the subsequent decomposition of part of the chloritic rock may have furnished materials for the formation of a rock of a totally different character, which is found in the same parish, and about three miles east of the locality from which this schistose rock was obtained, or about two miles to the west of Castlefinn (both localities being north of the river Finn). It is marked as metamorphic limestone on Sir Richard Griffith's Geological Map of Ireland. It has a saccharoidal structure, and a greyish white colour, the grey tint being due to micaceous scales of chlorite which are disseminated through the mass, together with some small crystals of magnetic and common iron pyrites and debris of hyaline quartz.

A fragment of this rock digested in dilute hydrochloric acid, left a residue analogous to that left by the schist when treated in a similar manner. The residue consisted of debris of fragments of hyaline quartz, sometimes agglomerated together and intermixed with fragments of the rock more or less decomposed. The crystals of pyrites which occur in the residue are always cubes with perfectly sharp edges and angles, the latter being sometimes truncated. There is every reason to suppose that these crystals were formed subsequently to the interval which gave birth to the limestone. Some of them were found in the midst of the quartz debris; and one of them consisted of a kind of twin parallel to the faces of the cube, the two halves being, however, separated by a portion of quartz; one half had its edges truncated and the other not. They had thus submitted to the conditions imposed by the medium in the midst of which they were developed.

The following are the results of an analysis of a specimen of this limestone:—

Carbonate of lime	75·987
Carbonate of magnesia	0·986
Peroxide of iron and alumina	1·583
Residue consisting of chlorite, magnetic, and common iron pyrites and debris of hyaline quartz	21·356
	99·912

It results from these observations that this metamorphic limestone should be regarded as derived from some of the materials of the schist above mentioned. For we may, so to speak, follow the passage of the mica-schist from the point where it does not effervesce with acids, into metamorphic limestone still containing all the essential parts of the schist. If we suppose that this limestone had been subjected to a high temperature, the quartz should have combined with the bases. The crystals of pyrites disseminated through the mass, as well as the position which they occupy, suggest an argument of a similar kind.

7. *Gweedore Metamorphic Limestone.*—This rock is found associated with mica-schist resting on granite near Gweedore River; isolated patches of the limestone occasionally rest on the granite, and sometimes alternate with mica-slate. This limestone is saccharoidal, of an aquamarine tint, which is due to the mass of small angular fragments of a green mineral interspersed through it. This mineral often serves as a nucleus to a crystal of carbonate of lime, and is accompanied by small sand-like crystals of idocrase and garnet. Large crystals of garnet are also found in abundance; and from the way in which they are deposited, the rock has a stratified appearance. The faces of the crystals are more or less eaten away, as if they had been weathered.

Treated for some time with very dilute hydrochloric acid, this rock gave in 100 parts the following results:—

Residue consisting of	Garnets, idocrase, and green mineral	17·16	23·360
	Amorphous silica	6·03	
	Alumina	0·17	
Carbonate of lime			75·250
Carbonate of magnesia			0·610
Alumina and oxide of iron soluble in acids			0·512
Water			(undetermined)
			99·732

If a fragment of this garnet limestone be left in very dilute hydrochloric acid until the whole of the carbonate of lime be removed, the garnets will be found imbedded in nearly pure amorphous silica, which readily dissolves in a weak solution of caustic potash. This siliceous paste is obviously the skeleton of a former rock. In the generality of instances silica is disseminated through the mass, and then does not form a coherent skeleton, so that the garnets, instead of being surrounded with the amorphous silica, are only coated on some sides with a siliceous film.

Cases also occur in which there is no silica, and the limestone contains only a small quantity of the above mentioned green mineral. In fact every analysis of the rock will give a different result as regards the quantity and nature of the residue.

The analysis of the green mineral was attended with great difficulty in consequence of the fine state of division in which it occurred, besides being mingled with idocrase and garnet debris nearly as fine as itself. A small quantity of it, picked out with the aid of a lens, yielded the following results:—

Lime	26·183
Magnesia	8·825
Protoxide of iron	10·576
Alumina	3·750
Silica	49·641
Water	1·025
	100·000

These numbers show that it is an aluminous augite, or more properly an augite and garnet compound, corresponding in a most striking manner with one from Fassa analysed by Kudernatsch*; the sum of the oxygen in the protoxide bases being 13·360 for the green mineral, and 13·658 for the specimen from Fassa.

As broken fragments of minerals cannot have been formed by the action of heat upon a sedimentary limestone, the fragmentary state of the green augite, idocrase, and garnets prove that the rock under discussion has not been metamorphosed by heat. On the other hand, the existence of an envelope of soluble silica surrounding some of the garnets, seems to show that anterior to the formation of the new limestone rock, one existing of silicates must have existed there.

Experiments to determine the Efficiency of Continuous and Self-acting Breaks for Railway Trains. By William Fairbairn, *F.R.S.*

Of late years various improvements have been introduced upon railways to diminish the dangers of travelling, and attention is now specially directed to the increase of the retarding power for trains by various kinds of breaks. From an early period in the history of railways it was seen that few objects were more important for ensuring the security of passengers and reducing the loss of time occasioned by stoppages, than the attainment of some means of destroying the momentum of trains with ease and rapidity, that is, in the least time and in the shortest distance. The less the time requisite to break a train, the longer the steam may be kept on in approaching a station, and the less is the loss of time in stopping; and the shorter the distance in which a train can be brought to a stand, the less danger is there of collision with obstructions on the line perceived not far off ahead. It is already allowed by many of those connected with railways, and has been expressly stated by the Lords of the Committee of Privy Council for Trade, that the amount of

* Gmelin, Handbuch d. Chemie, Bd. 2. p. 383. 4 Auf.

break power habitually supplied to trains is in most cases insufficient; and their Lordships enumerate thirteen accidents from collision occurring in 1858, the character of which they consider would have been materially modified, if not altogethr prevented, by an increased retarding power under the command of the guards of the trains.

Upon this subject the most important communication hitherto made has been the Report prepared by Colonel Yolland for the Railway Department of the Board of Trade, and containing a large number of experiments with heavy trains at high velocities. The breaks with which Colonel Yolland experimented were those which, as improvements on the common hand break, have hitherto commanded most success. These were the steam-break of Mr. McConnel, the continuous break of Mr. Fay, the continuous self-acting break of Mr. Newall, and the self-acting buffer-break of M. Guerin. The general conclusions to which Colonel Yolland was led by his experiments, resulted in the recommendation of the break of Mr. Newall; and for heavy traffic, a provisional recommendation of the break of M. Guerin.

From a misunderstanding caused by this Report of Colonel Yolland, arose the necessity for some further experiments on the similar breaks of Mr. Fay and Mr. Newall; and these I was called upon to arrange and carry out by the Directors of the Lancashire and Yorkshire Railway. I propose to lay before the Association a brief abstract of these experiments, with some remarks upon the conclusions to which they give rise.

It will not be necessary here to describe minutely the details of the construction of these breaks. They consist essentially of a series of break-blocks acting upon every wheel of the carriages of the whole train or some part of the train, the break-blocks being suspended as flaps, or placed on slide bars beneath each carriage, as in the ordinary arrangement of the guard vans. But whereas it would be both expensive and inefficient to work these breaks with a guard or breaksman to each carriage, both Mr. Fay's and Mr. Newall's patents provide for a continuous shaft, carried the whole length of the train, beneath the framing and with suitable jointed couplings between each pair of carriages, so that they may be undisturbed by the rocking motion of the train or the action of the buffers. In this way the whole of the breaks may be worked by a single person at either end of the train, communicating his power to each break through the agency of the continuous shaft.

Again, there have been applied, in the first instance by Mr. Newall, and subsequently by Mr. Fay, powerful springs beneath each carriage, connected with the arms of the rocking shaft, by means of which the breaks are made to act instantaneously throughout the train, on the release of a catch or disengaging coupling in the guard's van. The value of this provision for the immediate and simultaneous action of the whole of the breaks, in cases where an obstruction is perceived upon the line, will be at once evident. It is one of the most important features of these breaks.

In carrying out the views of the Directors of the Lancashire and Yorkshire Railway Company, it was arranged, in order to test the relative efficiency of these breaks, to have a series of experiments upon the Oldham incline of 1 in 27. On this gradient a train of carriages, fitted with Mr. Newall's self-acting slide breaks, and a similar train fitted with Mr. Fay's continuous flap breaks, were started in turn, and after having passed over a measured distance by the action of their own gravity, the breaks were applied and the distance along the incline in which the trains were respectively brought up was carefully ascertained as a measure of the retarding force of each. The trains employed consisted of three weighted carriages each, and having been placed upon the incline, they were started by removing a stop. Having then descended a previously measured distance with a uniformly accelerating velocity, they passed over a detonating signal which conveyed notice to the guard to put on the breaks. Then the train having been brought to a stand, the distance from the fog-signal to the point at which the train stopped was measured, and the train brought back for another experiment. In this way it was easy to obtain an initial velocity of 50 feet a second, or 35 miles an hour before applying the breaks.

Unfortunately the day upon which these experiments were made proved misty and foggy with rain at intervals, so that the rails were in the very worst condition for facilitating the stoppage of the train. The significance of this fact will be seen on comparing the retarding power of the breaks in these experiments with those made in fine weather.

Reducing the results, we find that the retarding force exerted by each break in terms of a unit of mass, calculated from the distance of pulling up, was equivalent to the numbers in the following Table :—

Experiments on the Oldham Incline.

No. of Experi-ments.	Mr. Newall.			Mr. Fay.		
	Velocity of train in feet per second.	Time in stopping in seconds.	Retarding force of break.	Velocity of train in feet per second.	Time in stopping in seconds.	Retarding force of break.
1	25·71	14	1·32	25·71	13	1·91
2	30·00	16	1·63	30·00	13	1·79
3	37·50	17	1·70	37·50	14	1·84
4	42·85	25	1·69	41·37	15	1·76
5	42·85	14	2·01	40·66	12	2·02
6	48·38	19	1·78	48·38	25	1·72
7	52·94	17	2·04	50·00	17	1·91
Mean...	....	21·6	1·74	....	19·2	1·85

The general result of these experiments gives a retarding force of 1·74 lb. per unit of mass for Mr. Newall's break, and 1·85 for Mr. Fay's; or in other words, Mr. Newall's break exerted a retarding force of 121·3 lbs. per ton weight of the train, and Mr. Fay's a retarding force of 129 lbs. per ton.

I afterwards arranged for some further experiments at Southport upon a piece of level rail between that town and Liverpool. The speed requisite in this case had to be obtained by the aid of an engine which was detached by a slip coupling at the instant of applying the breaks. In other respects these experiments were conducted like the preceding with fog-signals, and the time noted by stop-watches. The weather, however, was in this case fine and dry, and hence the following results were obtained in the most uniform circumstances.

The friction of the train itself, and the resistance of the air, were ascertained to amount with Mr. Newall's train to 6·4 lbs. per ton, and with Mr. Fay's train to 10·4 lbs. per ton.

In this case we have a retarding force per unit of mass equivalent to 5·49 lbs. in Mr. Newall's break, and 6·7 lbs. in Mr. Fay's; or in other words, the retarding force of the slide breaks of Mr. Newall, from eight experiments, at velocities varying from 35 to 60 miles an hour, was equivalent to 382·6 lbs. per ton weight of the train.

The retarding force of Mr. Fay's slide break from eight similar experiments, at velocities varying from 33 to 63 miles per hour, was equivalent to 466·4 lbs. per ton weight of the train.

Experiments at Southport.

Slide Breaks. Engine detached.

Mr. Newall.			Mr. Fay.		
Speed in miles per hour.	Distance of pulling up in yards.	Retarding force of break.	Speed in miles per hour.	Distance of pulling up in yards.	Retarding force of break.
32·72	56⅔	6·77	35·29	56	7·97
36·73	77	6·28	43·90	98	7·05
43·90	136	5·08	50·00	129	6·94
46·15	140⅔	5·42	54·54	144	7·40
52·94	205⅓	4·89	54·54	161⅔	6·59
54·54	192	4·66	37·89	97	5·30
47·37	260⅓	—	60·00	204⅔	6·30
53·73	222	5·23	60·00	214	6·03
63·16	273	5·55			
	Mean...	5·49		Mean...	6·70

Flap Breaks. Engine detached.

Mr. Newall.			Mr. Fay.		
Speed in miles per hour.	Distance of pulling up in yards.	Retarding force of break.	Speed in miles per hour.	Distance of pulling up in yards.	Retarding force of break.
50·00	132⅔	6·75	51·43	158⅓	5·98
50·00	123	7·28	51·43	162⅔	5·82
51·43	192	4·93	54·54	184	5·79
	Mean...	6·32		Mean...	5·87

These experiments give for the retarding force of Mr. Newall's flap break 6·32 lbs. per unit of mass, and for Mr. Fay's 5·87 lbs.; or in other words, the retarding force of Mr. Newall's flap break, from three experiments, at velocities varying from 50 to 51½ miles per hour, was equivalent to 440·3 lbs. per ton weight of the train.

The retarding force of Mr. Fay's flap breaks, from three similar experiments, was 408·6 lbs. per ton.

We may illustrate the general bearing of these experiments by estimating from an average of the whole experiments the distance required to stop a train fitted throughout with these breaks, and detached from the engine.

A train would be stopped,—

At a	velocity of	20	miles an	hour in	23·4	yards.
,,	,,	30	,,	,,	52·9	,,
,,	,,	40	,,	,,	93·8	,,
,,	,,	50	,,	,,	146·8	,,
,,	,,	60	,,	,,	211·5	,,

This last Table exhibits in a very clear manner the advantages of this class of breaks, in which the whole weight of the train aids in destroying the momentum of the mass instead of the weight of one or two guard vans only. It may be impossible in long trains to apply these breaks to every carriage; but, at all events, in the ordinary traffic three times the present amount of break power may be employed with ease.

On the score of economy also, the system appears to encourage its application; from experiments which have been made, it appears that the wear of the tyres is far more uniform and equal, because the break springs may be so adjusted as not to cause the wheels to skid. The Manager of the East Lancashire Railway states that with two trains running together between Salford and Colne, the carriages fitted with continuous breaks travelled 47,604 miles before the wheels required turning up; whilst an ordinary break van running the same distance had to have its wheels turned up three times in the same period, three-eighths of an inch being taken off each time.

Experiments at Southport.

Engine not detached from the Trains.

Mr. Newall.		Mr. Fay.		Remarks.
Speed per hour.	Distance of pulling up.	Speed per hour.	Distance of pulling up.	
miles.	yards.	miles.	yards.	
33·96	$124\frac{2}{3}$	31·8	$121\frac{2}{3}$	Engine and tender.
37·11	$169\frac{1}{3}$	33·96	137	Tender and continuous
41·86	221	41·86	$192\frac{1}{3}$	breaks applied.
		51·43	274	Tank engine.

It will be observed that on most through lines the trains travel on some portion of the distance at the rate of 60 miles an hour, and in the event of an obstruction half a mile in advance, a collision would be inevitable unless the driver has the power and the presence of mind to act with promptitude. Now at 60 miles an hour there is only 30 seconds, or half a minute, to effect that object, and it is quite impossible to apply the breaks in their present state, before the train, in such a precarious position, is in actual contact. Assuming, however, that breaks upon the principle of Mr. Newall and Mr. Fay were attached to the engine as well as the train, and that the driver had the power of instantaneous application by liberating a spring, it is evident that, instead of the train dashing forward to destruction, the momentum might be destroyed in a distance of less than 500 yards, and that without injury to life or property. Besides, the application of the Electric Telegraph, which prevents on most through lines more than one train being on the line between the stations, is a great additional security, and that, united to the continuous break, *applied to the engine as well as the train*, would—when united to a more perfect system of signals—render collision next to impossible.

Report of Dublin Bay Dredging Committee for 1858–59. *By* Professor J. R. Kinahan, *M.D., F.L.S., M.R.I.A.*

The Dredging Committee, appointed at the Leeds Meeting in 1858, consisted of Professor Kinahan, Dr. Carte, Dr. E. Perceval Wright, F.L.S., and Professor J. Reay Greene.

Early in the winter of 1858, the author commenced investigations at the south of the district on the Scallop Bank near Bray, to which three excursions were made with success, as regards the captures made. Early in 1859 a series of severe gales occurred, which afforded a rich harvest of specimens on the Portmarnock Strand to the north of Dublin; many species of Mollusca, Crustacea, &c., ordinarily of rare occurrence, having been thrown up in abundance living on the beach, betokening a serious disturbance of the banks in the neighbouring seas. The following may be enumerated:—*Cochlodesma prætenue, Fissurella reticulata, Emarginula reticulata, Mactra elliptica, Tapes virginea*, var. *Sarniensis* (very abundant), *Thracia villosiuscula, Thracia phaseolina, Thracia convexa* (a single valve).

Inachus Dorsettensis, Pilumnus hirtellus (chiefly broken), *Portunus holsatus, Portumnus variegatus, Corystes Cassivelaunus, Nephrops Norvegicus* (all broken, but in great profusion), *Cribella oculata, Asterias aurantiaca, Spatangus purpureus, Thyone papillosa, Priapulus caudatus*, &c.

The results of these investigations have been all noted, but unfortunately an inflammatory attack of the eyes, of some months' duration, put a stop, on the author's part, to the completion of the labours which had been commenced.

Dr. E. Perceval Wright in the month of June undertook the particular examination of the district in the neighbourhood of Ireland's Eye; the results of his investigation, which are not yet completed, he hopes to include in the next year's Report.

From the materials now at their disposal, your Committee hope next year to be able to present a more systematic Report, as the results obtained, though important, are not sufficiently numerous to enable them to do so yet; they have therefore to request that the same Committee, Professor Kinahan, Dr. Carte, Dr. Perceval Wright, and Professor Greene, may be reappointed, and that a further sum of £15 may be allocated for this purpose.

Report on Observations of Luminous Meteors, 1858-59. *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.*

IN submitting the present continuation of my series of reports on luminous meteors I have little to say beyond what the results themselves indicate. I am indebted to the same friends as on former occasions for some valuable communications. Among these I may just refer to the observations of Mr. Lowe as including a notice of the periodical meteors of August the 10th of the present year, up to the amount of 70 per hour, and all diverging from a point in Perseus. In many parts of England the evening was cloudy. But at the observatory of Lord Wrottesley these meteors were well seen by Mr. F. Morton, who has communicated some interesting particulars respecting them, which are given in the sequel.

The November meteors of 1858 were observed by the Abbé Leconte, at Hainault. It is to be regretted that no observations have been communicated of a nature to verify the theory of Sir J. Lubbock, and it is still more remarkable, that since the first announcement of Mr. Pettit of the distinct establishment of the existence of one, if not two, minute satellites to our earth, no further observations either of these or of any others, many of which may be presumed to exist, have been published. A valuable paper has appeared in the 'Philosophical Magazine,' June 1859, 'On the Periods and Colours of Luminous Meteors,' by Dr. J. H. Gladstone, in which the author brings together a number of important results and remarks, mainly founded on the observations of M. Poey, as well as upon the data furnished by the Catalogues of the British Association. In the Appendix I subjoin a brief analysis of the leading contents of this valuable investigation.

Observations of Luminous Meteors,

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1858. Oct. 24	h m s 6 17 30	=Arcturus............	Colour of Arcturus.	No streak or separate streams.	Fell slowly. Duration 1 sec.
Nov. 11	....	....	....	....	....
Nov. 12	....	....	....	....	....
1859. Feb. 23	11 20 31	Increased in size from =1st mag.* to $\frac{1}{5}$th size of ☾.	Very bright. *Intense blue.* The separate fragments when it burst *yellow.*	Slight streaks in its path, and burst into separate fragments, which instantly disappeared. The star η Ursæ Majoris was crossed by these fragments.	Moved slowly, duration 8 sec.
Mar. 30	9 15	=½ size ☾	At first *red*, then slowly changing to *pink*, and finally to *orange*. Bright enough to see time from a watch.	Trail of light left in its track.	Duration 50″......
April 4	....	....	....	....	....
April 22	1 14 30	=3rd mag.*...........	Orange scarlet.	Leaving streaks in its path.	Rapid ....
April 22	2 27 a.m.	=4th mag.* increasing to twice size of 1st mag.*	*Blue* until it entered the dark segment of an arch, when it instantly increased in size, and changed to an *orange* colour.	Leaving streaks.	Rapid. Suddenly disappeared.
Aug. 1	....	....	....	....	....
Aug. 8	....	....	....	....	....
Aug. 9	....	....	....	....	....

by E. J. Lowe, Esq., F.R.A.S., &c., 1858-59.

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
Perpendicularly down, passing 15′ N. of Arcturus.	A well-marked meteor.	Observatory, Beeston.	E. J. Lowe, Esq.	MS.communication
....	Many meteors, especially about 11p.m., all small, from 4th to 5th magnitude.	Ibid	Id.	Ibid.
....	Many meteors, all small and having very rapid motions. The 13th and 14th overcast.	Ibid	Id.	Ibid.
From close to τ Ursæ Majoris to η Ursæ Majoris, where it suddenly vanished. Place of disappearance Æ. 13h. 41m. Decl. 50° 1′ N.	This magnificent meteor was pear-shaped. Had a well-defined edge. Increased in size, and disappeared at its maximum. There were streams of Aurora Borealis immediately below the place where the meteor started from.	Ibid...............	Id.	Mr. Lowe's MS.
From above Ursa Major, towards the N. at an angle of 60°, and passing midway between the Great and Little Bears.	At its maximum brightness when first seen.	Highfield House, near Nottingham.	W.Richards,Esq.	Ibid.
....	Several meteors.	....	E. J. Lowe, Esq.	Ibid.
From altitude 40° N. downwards at an angle of 40° towards W., and moving 10°.	Deeper in colour than a fine Aurora which was visible at the time.	Observatory, Beeston.	Id.	Ibid.
From 80° above N.W. horizon fell perpendicularly down.	Aurora Borealis ...	Ibid	Id.	Ibid.
....	Many meteors	Ibid...............	Id.	Ibid.
....	Overcast	....	Id.	Ibid.
....	Overcast	....	Id.	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1859.	h m s				
Aug. 10	....	After 11 p.m. nearly cloudless. Very many meteors, especially between midnight and hour, and, as only a fourth part of the heavens was watched, this multiplied by were of the second magnitude, but, as the moon did not set till half past 1, pro- her light. These meteors, with two or three solitary exceptions, could all be between α and β Persei. Several marked features were observed. Those me- *moved more rapidly* and over *a larger space* than those nearer to this point. moved over a few minutes of space, and one meteor which I was fortunate enough *creased in size, and disappeared, without moving.* Most of the meteors were gering streaks. The numbers increased up to 3 a.m..			
Aug. 11	1 29 a.m.	= ♃....................	Blue...........	Train.	Rapid streaks.......
Aug. 11	1 32 a.m.	Increased from a point to that of a 1st mag.*, and again decreased to a point.	Bluish..........	There were brief streaks shot out from it.	Duration 0·5 sec...
Aug. 11	10 & 12 p.m.	....	....	....	....
Aug. 29	2 50 a.m.	= 1st mag.*...........	Orange.........	Streak........................	Rapid.................
Aug. 29	3 15 10	2nd mag.*	Blood red......	Streaks widened	Rapid.................
Aug. 29	3 15 20	3rd mag.*...............	Colourless.	Streaks.	Rapid.................

Observations of Luminous Meteors

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1858.	Local mean solar time.				
Mar. 23	11 44 46	Much brighter than Capella.	....	....	....
May 5	2 39½ a.m.	Brighter than ♂. ...	....	Disappeared instantly without diminution of brightness.	More than 5 secs., perhaps 7 or 8 secs.
Sept. 12	During the night.	A number of meteors chiefly in or near the Milky Way.	....	Some left trains............	....
Oct. 1	7 54 p.m.	....	....	....	....
Oct. 5	0 53 26	....	....	....	....
Oct. 9	6 33 23	Bright....................	....	....	....
1859.					
Jan. 2	10 11 p.m.	A great number of meteors.	....	....	About 1 per minute.
Mar. 18	1 23½ a.m.	Magnificent meteor.	Golden hue....	Left a few sparks.	Disappearance not noted.
April 6	During the night.	Great number in all parts.	....	....	....

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
2 a.m.; the number seen was about 70 per 4 would give 280 per hour. Most of them bably the smaller ones were eclipsed by traced back to a point situated midway teors the furthest removed from this point Close to the point, the meteors only to detect *on this very point, appeared, in-* *yellowish* in colour, and had short lin-		Observatory, Beeston.	E. J. Lowe, Esq.	Mr. Lowe's MS.
From midway between Algol and Polaris, down towards N.W. horizon at an angle of 45°.	....	Ibid................	Id.	Ibid.
A stationary meteor, at the point of convergence of all the meteors situated half-way between α and β Persei.	It did not move amongst the stars.	Ibid..............	Id.	Ibid.
Above a dozen meteors seen gave the same point of divergence. The meteors much less numerous to-night.	....	Scarborough ...	Id.	Ibid.
Fell across Aurora Borealis perpendicularly down from slightly E. of Gemini.	Brilliant Aurora.	Observatory, Beeston.	Id.	Ibid.
Shot from the cupola of the Aurora, which was situated near γ Andromedæ, and moved towards γ Arietis.	Aurora Borealis brilliant.	Ibid..............	Id.	Ibid.
Another shot from the same spot, moving to β Andromedæ.	....	Ibid	Id.	Ibid.

at Wrottesley Observatory.

Descending for 10° above the pole towards W. horizon.	Moon shining. Meteor seen through opening of equatorial.	Wrottesley Observatory, Wolverhampton.	Mr. F. Morton.	MS. communication
In E. moving slowly southward, altitude 15°, parallel to horizon through about 35°.	....	Ibid	Id.	Ibid.
....	....	Ibid	Id.	Ibid.
10° below pole, parallel to horizon.	....	Ibid	Id.	Ibid.
In S. going W., at altitude 35° or 40°.	Many smaller during the night in various parts.	Ibid..............	Id.	Ibid.
In Pegasus....	....	Ibid..............	Id.	Ibid.
....	....	Ibid..............	Id.	Ibid.
From S. to N. a few degrees below the moon.	Seen through opening of dome. Moon full.	Ibid	Id.	Ibid.
....	....	Ibid	Id.	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1859.	h m s				
Aug. 10 / Aug. 11	....	Great display of meteors.	....	....	....
Aug. 21	10 13 p.m.	Much brighter than Capella.	....	Followed by splendid train of sparks, visible some seconds after disappearance.	5 or 6 secs. ....
Aug. 23	1 13 a.m.	Brilliant flash through opening to dome.	....	....	....

Observations of Luminous Meteors

1858. Dec. 2	4 5 p.m. Daylight.	Large....................	....	Train for a few seconds.	Velocity moderate..
Id.	Id.	....	Bright, but not dazzling.	(Train red, a mere impression on the eye.)	Motion slow. ....
Id.	Id.	Larger than * of 1st magnitude.	Bright blue...	Train of sparks.	First ascended and then descended.
	Id.	....	....	....	....
Dec. 5	A few minutes after sunset.	....	Very brilliant.	After a few seconds train white in place of first appearance (wavy), vertical, then changed to horizontal, in 15 minutes disappeared.	....
1859. Mar. 23	A few minutes past 8 p.m.	Large....................	Brilliant........	....	....
Jan. 2	8 30 p.m.	=2 Jupiter.............	Bright..........	Left a train for 1 or 2 seconds.	....
	Half a minute later.	....	A smaller meteor.	....	....
June 21	0 20 a.m. G. M. T.	=♀.....................	Orange.........	Train of sparks: opake, short.	About 5 secs. ......
Sept. 2	12 p.m.	=1st mag.*............	Bluish very pale.	Left a long thread of light behind.	About 1 sec.... .....
Sept. 3	11 25 p.m.	=4th or 5th mag.*...	....	....	Rapid, not ½ sec. ...
June 26	11 52 p.m.	Diameter 15′, globular.	Bluish..........	....	....
	About 11 0 p.m.	Nearly globular.	Highly luminous, but not very brilliant(?)	No tail, no connexion.	Descended gently..
	About the same time.	....	....	....	Descended gently and steadily.
	....	....	....	....	....

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
....	See Appendix.	Wrottesley Observatory, Wolverhampton.	Mr. F. Morton...	MS. communication.
From S.E. at altitude 35°, through 40°, disappeared in SS.W.	....	....	Mr. W. P. Wakelin.	Ibid.
In E.S.E.	Moon bright.	....	Mr. F. Morton...	Ibid.

from various Observers.

From zenith towards E., disappeared at altitude 45°.	....	Buckbury Hill, Mordiford, Herefordshire, 4 miles E. of Hereford.	Dr. C. Lingen ...	Letter communicated by Mr. J. E. Smith, Hereford Infirmary.
Towards N.E., disappeared at altitude 70°, moving obliquely from N.W. through 8°.	Sun shining brightly, a few light clouds.	Brighton	Mr. T. B. Lane.	Ibid.
Disappeared at between 20° and 30° altitude, towards S.E. from N.W.	No report.	Derby	Mr. F. T. Dubois.	Ibid
Disappeared at about 40° altitude towards S.W., commencing from 45°.	Clear sky.	Belleau, Alford, Lincolnshire.	Mr. J. W. Giles.	Ibid.
Falling perpendicularly from altitude 30° in W.	Barometer 29·30. Ther. 76°. Evening clear, many falling stars.	Lat. N. 13° 20, Long. E. 50, on board ship "Emeu."	J. H. Hood, Member of Council, Sydney.	Letter to Royal Society, communicated by Prof. Stokes, Sec. R. S.
Vertically down from N.W. to E. of Cassiopeia.	Lost behind houses.	Tunbridge Wells, Grove-hill.	Miss Powell.	MS. communication.
From near Aldebaran to near ϵ Eridani.	....	Dunster, Somerset.	W. Symons.	Id.
Between Orion and Procyon nearly same direction.	....	Ibid	Id.	Id.
Moved in the arc of a great circle 40° or 50°, the middle passing through the zenith, from S.W. to N.E.	....	More Cottage, Glasgow, 3 miles S. of the Observatory.	W. J. Macquorn Rankine, Esq.	Id.
From S.W. to W.	....	Dunoon, 25 m. west of Glasgow.	W. Crawford, Esq.	Id.
From Polaris towards W.	....	Glasgow	Id.	Id.
Vertically downwards. First seen at 30° from zenith.	Weather cloudy and hazy, with lightning; indistinctly seen.	London	G. P. Greg, Esq.; his brother, and J. Breen, Esq.	MS. communication from Mr. Greg.
....	No report or explosion, much lightning in the same quarter.	Hertfordshire ...	Id.	Ibid.
High up in the E., descended vertically to horizon.	No thunder or lightning.	Bolton, South Lancashire.	Id.	Ibid.
....	Seen, but particulars not given.	Halifax, Yorkshire.	Id.	Ibid.

Observations of Meteors by Dr. J. H. Gladstone, F.R.S., &c.

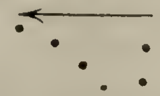
Date.	Hour.	Apparent size.	Colour.	Train.	Duration.	Direction.	Remarks.	Place.
1858. Sept. 18	h m 10 26 p.m.	=1st mag.*	White.	Momentary train.	About 1 second ...	It passed horizontally over Ursa Major, as shown in diagram,  and for the distance there indicated.		Southsea.
Sept. 26	8 25 p.m.	Brighter than 1st mag.*	....	Momentary train.	Rapid	From about the zenith into Bootes.	....	Leeds (seen by Mrs. J. H. G.).
Oct. 9	....	Many small shooting stars.	....	....	....	....	....	Acton.
1859. July 29	10 7 p.m.	Brighter than 1st mag.*	White.	None	Slow, about 2 secs.	Fell from S.E. by E. almost perpendicularly, from an altitude of about 35° to about 25°. It bent somewhat in its course.	It appeared to myself and another observer much nearer than the fixed stars.	Berwick Pier.

TABLE showing the Number of Meteors observed to pass between the respective Constellations, as recorded in the List of G. J. Symons, Esq., M.B.M.S.

From	To Bootes.	Aquila.	Auriga.	Sagittarius.	Ophiuchus.	Hercules.	Corona Borealis.	Ursa Major.	Serpens.	Coma Berenices.	Lyra.	Andromeda.	Cygnus.	Perseus.	Orion.	Cetus.	Canis Major.	Draco.	Delphinus.	Pegasus.	Gemini.	Piscis Australis.	Sculptor.	Leo.	Libra.	Capricornus.	Total.
Cygnus	...	4	...	...	1	...	...	...	...	...	...	...	1	...	...	...	...	1	1	...	...	...	...	...	...	...	8
Draco	...	...	...	...	...	3	...	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5
Ursa Major	2	...	...	...	...	...	1	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5
Auriga	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	1	1	...	...	...	...	...	4
Gemini	...	...	1	...	...	...	...	...	...	...	...	...	...	1	2	...	...	...	...	...	...	...	...	...	...	...	4
Lyra	...	...	...	...	2	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3
Cassiopeia	...	...	...	...	...	...	...	...	...	...	...	2	...	1	...	...	...	...	...	...	...	...	...	...	...	...	3
Aquila	1	...	...	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3
Delphinus	...	...	...	1	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	3
Hercules	1	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3
Corona Borealis	1	...	...	...	...	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3
Perseus	...	...	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3
Ophiuchus	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	2
Bootes	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	2
Ursa Minor	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Pleiades	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Pegasus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	1
Cetus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	1
Andromeda	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	1
Taurus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	1
Leo	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	1
Total	5	5	5	4	4	4	3	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	58

Observations of Luminous Meteors, by G. J. Symons, Esq., M.B.M.S., at 27 Queen's-road, Camden Town, London.

Date.	Time.	Mag.	Colour.	Train.	Direction.
1858.	h m s				
Sept. 5	9 21 p.m.	1	white	none	From δ Ursæ Majoris towards θ Ursæ Majoris. (Bright, very slow.)
6	9 53 p.m.	$>2\times1$	blue	broad	From Polaris towards Corona Borealis.
	9 59 p.m.	2	white	none	From α Ophiuchi towards the horizon.
	10 9 p.m.	2	white	slight	From 5° N. of Vega towards α Ophiuchi.
	10 28 p.m.	2	white	none	From β Cygni towards ζ Aquilæ.
12	7 22 p.m.	2	white	none	From Corona Borealis towards η Ursæ Majoris.
	7 25 p.m.	$=2\times1$	red & blue	30° long	From δ Ursæ Majoris towards Arcturus.
	7 25 30 p.m.	1	red	slight	From η Coronæ Borealis towards ε Bootis.
	9 28 30 p.m.	3	white	none	From β Cygni towards β Ophiuchi.
	9 29 p.m.	2	white	none	From η Ursæ Majoris towards Coma Berenices.
Oct. 31	8 58 20 p.m.	2	white	none	From ε Persei towards δ Aurigæ.
	9 8 p.m.	2	white	none	From ε Persei towards δ Aurigæ.
	9 12 p.m.	4	white	none	From Capella towards Jupiter.
	9 33 p.m.	2	white	none	From Pleiades towards Aquila. (The longest course I ever observed.)
	9 39 p.m.	2	white	none	From γ Pegasi towards Fomalhaut.
	9 40 20 p.m.	>1	white	long	From Capella towards α Ceti.
	9 53 p.m.	3	white	none	From Algol towards Capella.
	11 11 30 p.m.	1	white	none	From τ Ceti towards α Sculptoris.
Nov. 9	7 58 30 p.m.	2	white	none	From π Cygni towards λ Draconis. (Slow.)
	8 9 p.m.	3	white	none	From ζ Cygni towards α Delphini.
	8 29 p.m.	1	white	none	From δ Draconis towards α Lyræ. (Swift.)
	8 41 p.m.	2	white	none	From γ Lyræ towards α Ophiuchi.
10	7 40 p.m.	2	white	none	From γ Draconis towards ρ Herculis.
	7 45 p.m.	2	white	none	From γ Cygni towards Albireo.
	8 18 30 p.m.	1	white	none	From γ Cassiopeiæ to α Andromedæ.
	8 21 p.m.	3	white	none	From β Draconis towards ς Herculis.
	8 28 p.m.	1	white	none	From λ Andromedæ towards γ Cygni.
28	9 1 50 p.m.	1	white	40° long	From β Aurigæ towards π Pegasi.
1859.					
Jan. 22	9 4 p.m.	2	white	none	From ν Geminorum towards γ Orionis.
	9 8 p.m.	3	white	none	From ψ Tauri towards α Ceti.
April 6	8 50 p.m.	2	white	none	From ε Leonis towards ζ Leonis.
6	8 53 p.m.	>1	white	none	From α Geminorum towards α Persei.
21	9 30 30 p.m.	2	white	slight	From α Geminorum towards α Orionis.
May 12	9 4 10 p.m.	♃	white	slight	From 5° below α Geminorum towards Jupiter. (Well seen, though bright moonlight.)
July 4	9 52 p.m.	5×1	See Note (1).	See Note (1).	From η Ursæ Majoris towards Corona Borealis.
	11 37 p.m.	2×1	yellow	none	From α Herculis towards ε Bootis. (Very slow.)
Aug. 2	0 32 a.m.	1	yellow	slight	From α Herculis towards μ Sagitt. (Slow.)
	0 43 a.m.	2×1	white	none	From μ Lyræ towards γ Serpentis. (Very swift, seemed close.)
	0 46 a.m.	1	white	none	From α Delphini towards β Lyræ. (Rapid.)
	0 52 a.m.	2	white	none	From μ Herculis towards μ Ophiuchi.
	0 59 a.m.	1	white	none	From ε Cygni towards γ Aquilæ.
	1 0 a.m.	2	white	none	From Altair towards Arcturus. (Slow.)
	11 35 p.m.	1	white	none	From θ Draconis towards γ Serpentis. (Swift.)
	11 42 p.m.	1	white	none	From π Bootis towards β Libræ. (Slow.)
3	0 2 a.m.	2	white	none	From γ Bootis towards Coma Berenices.
4	11 33 p.m.	2	white	none	From ρ Coronæ Borealis towards α Herculis.
	11 42 p.m.	2	white	none	From α Draconis towards γ Herculis.

Date.	Time.	Mag.	Colour.	Train.	Direction.
1859.	h m s				
Aug. 4.	11 44 p.m.	>1	white	none	From ζ Ursæ Majoris towards Arcturus.
	11 52 p.m.	2	white	none	From γ Cygni towards ζ Aquilæ.
	11 52 p.m.	4	white	none	From γ Cygni towards ζ Aquilæ.
	11 53 p.m.	1	white	none	From α Delphini towards τ Sagittarii. (Swift.)
	11 57 p.m.	1	white	none	From α Aquilæ towards Corona Borealis.
5	0 36 30 a.m.	3×1	See Note (2).		From β Ophiuchi towards μ Sagittarii.
11	10 40 40 p.m.	2×1	white	slight	From ρ Cassiopeiæ towards β Persei.*
	10 52 p.m.	2×1	yellow	sparks	From ε Cassiopeiæ towards β Andromedæ.*
	11 16 32 p.m.	2	white	none	From ζ Aurigæ towards Castor.*
29	1 5 a.m.	2	white	none	From β Aquilæ towards μ Sagittarii.
	1 31 a.m.	2	white	none	From Delphinus towards γ Capricorni.

(1.) This meteor was of very considerable apparent diameter, of a pale yellow colour; on exploding, the sparks assumed a bright crimson hue; it was remarkable for its very slow motion.

(2.) This meteor, when first observed, was little more than 2nd magnitude, but rapidly increasing in apparent diameter: it presented at its disappearance a well-defined disk. Its colour was a brilliant emerald green and the body of light such as to illuminate with the same tinge 30° or 40° of the adjacent sky. There were no sparks, and it was very similar to one or two I have seen before, and which I cannot better describe than as resembling a body of light enclosed in a filmy envelope.

APPENDIX.

No. 1.—Letter from Mr. Hood to the Royal Society, communicated by Professor Stokes, Sec. R.S.

Pt. de Galle, Ceylon, January 15, 1859.

SIR,—I beg to send you the accompanying description of a phenomenon observed on board the Steam-ship *Emeu*: as a similar one had never been noticed by any of the ship's officers or passengers, amongst whom were two captains of Her Majesty's Navy, it seems worthy of record.—I remain, Sir, your obedient servant, J. H. HOOD, Member of Council, Sydney, N.S.W.

On the 5th December 1859, lat. N. 13° 20′, Long. E. 50°, a very brilliant meteor was observed, a few minutes after sunset, in the west, falling perpendicularly from an apparent altitude of 30°. In a few seconds there appeared, in the place where the meteor was first visible, a bright white cloud, in shape , perpendicular to the horizon, and crossing the light transparent ruddy stratus-clouds; gradually it ascended slightly, and became horizontal, remaining nearly unchanged (but slowly moving on with the light breeze) for about fifteen minutes, when it gradually disappeared in the haze of the evening. Its appearance was very remarkable, in shape thus  and of a bright clear white colour, against the golden-coloured evening sky. The evening was very calm and remarkably cool, falling stars unusually numerous. Bar. 29·30. Ther. 76°.

No. 2.—Analysis of a paper by Dr. J. H. Gladstone, Ph.D., F.R.S., in the

* Observed at Thornton Viçarage, near Leicester.

'Philosophical Magazine,' June 1859, entitled "On the Periods and Colours of Luminous Meteors."

With reference to the explanations of the periodical star-showers, so often attempted, the author examines the speculations of M. Charles, and, from comparison with other ancient records besides those cited by that writer, comes to the conclusion that his ingenious hypothesis—viz. that there may be a secular progression of these periods, and that the showers of February, March, and April, in the middle ages may be the same as those which now recur in August—is untenable. "It rather appears that the periods remain stationary, sometimes for centuries, but the transit of these streams of meteors through our atmosphere is liable to interruptions and changes which we may speculate upon, but cannot yet determine."—p. 2.

With respect to the varied colours of meteors, on examining the numerous results collected by M. Poey, the author suggests whether we always correctly translate the names of colours used in records of such remote antiquity as those of the Chinese and others referred to. He also controverts the theory of M. Doppler (referred to in the last Report), and in general is disposed to hold that nearly all meteors may be arranged under two grand classes,—blue, and orange inclining more or less to red, while in passing from the zenith to the horizon changes of colour are constantly noticed. The trains are sometimes of different colour from the body, and the radiation of colour over objects is also often different from the colour of the meteor.

The author very justly remarks that observers often call the same colour by different names. But apart from this source of fallacy he conceives a real difference possible, and "that a meteor may emit rays which in the aggregate would produce one colour, and yet may affect the observer with a sensation of a different colour. This may arise from absorption, intensity, or contrast."—p. 7.

He then supports this view by several arguments and instances; in particular he conceives the absorption of the atmosphere, especially when saturated with vapour, may account for the change of colour in the passage of meteors, which generally terminate in red, known to be the ray most transmissible through mist.

It has been observed by Helmholtz and others, that light of any colour, if of high *intensity*, tends to give a sensation of *whiteness*. This the author thinks will account for the *radiance* different from the *colour* of the meteor; as well as for an apparent change of colour, with a change of intensity from passing through a dense atmosphere. All appearances of colour are greatly affected by *contrast*; hence he thinks the difference between the colour of the bodies and trains or other products of meteors may be explained in many instances.

The author examines the question whether there may be any relation between period and colour in meteors. Those occurring at one period may be of a different composition, and consequent colour in combustion, from those at another. Such a relation is supported by many of the comparisons of records made by M. Poey. The author also gives a tabular view, from which it results that "August is marked by a great deficiency of orange, and a great excess of blue meteors—while November exhibits comparatively few blue, and a very large proportion of orange meteors, with a slight increase of the red."—p. 9.

He finally observes that all meteors, whose composition is known, consist of many ingredients which may possibly all be ignited together, or separately, in different instances, thus giving out different rays for each component, and these again different for different intensities of combustion. In support of this view he refers to the known components, iron, sulphur, and phosphorus, as well as cobalt, zinc, nickel, &c., and the intense but greatly varied illuminations they give when in combustion, especially under the influence of galvanism, which resemble the light of meteors.

No. 3.—Miscellaneous Notes on Meteoric Phenomena and Theories.

In the Transactions of the American Philosophical Society of Philadelphia, vol. viii. New Series, Part I. 1841, the student of meteoric phenomena will find two valuable papers treating the subject, as connected with cosmical forces, and regarding meteors as planetary bodies revolving in our system about the sun, but under certain conditions perturbed by, and attracted to, the earth; both papers contain elaborate researches, of which it would be impossible here to attempt an analysis, investigating as problems of physical astronomy the nature and modifications of their orbital motions. They are entitled, Art. VIII. "On the Perturbations of Meteors approaching the Earth," by B. Pierce, M.A.; Art. IX. "Researches concerning the periodical Meteors of August and November," by Sears C. Walker, A.P.S.

In the 'Philosophical Transactions,' 1840, Pt. I. Sir F. Palgrave gives an account of some ancient records of meteors. An ancient chronicle, April 3, 1095, speaks of "stars driven like dust." July 26, 1243, Matthew of Paris describes falling stars seen 30 or 40 in one minute, so that "if they had been true stars, not one would have remained in the sky."

E. W. Brayley, Esq., 'Philosophical Magazine,' vol. lxiii. p. 385, 1824, and vol. lxiv. 1st Series; also vol. xix. 3rd Series, p. 500; and Annals of Philos. January 1824, p. 73, gives a variety of details respecting meteors and aerolites. In the last-mentioned paper he notices the fact that the meteorites which have been examined as to their density and composition form a continuous series of varying characters from the most compact iron to the most crystalline or scoriaceous stone.

The hypothesis of nebulous matter existing in masses analogous to comets, and like them revolving in our system, as the origin of meteors, has been supported on the strength of general analogy, and the probable extensive diffusion of this kind of matter as evinced in the continual discovery of new telescopic, as well as large, comets; so that we may well admit with Kepler that their number may be infinite, and the universe full of them. Such masses might be expected to undergo great retardation from a resisting medium, and ultimately to be condensed into the sun, or any solid planet to which they may be attracted; the retardation gradually contracting their orbits till they fall on the central body. It has been also alleged that in some instances the nebulous tails of comets, such as those of 1811 and 1823, may have mixed with our atmosphere, and perhaps from electric action have given rise to luminous phenomena having the appearance of shooting stars.

Several writers have speculated on the connexion of meteors with electric phenomena, or even their electric origin.

A hypothesis of this kind, supposing diffused atmospheric matter to be carried by electric currents, has been advocated by Professor Maas in the Bulletins of Royal Acad. of Brussels, 1847, p. 303.

On this subject the reader should refer to 'Cosmos,' 1st Translation, p. 123; and to some remarks of Poisson, *ibid.* note p. 402.

Also to the masterly paper of the late Mr. Galloway, F.R.S., F.R.A.S., in the 'Notices of the Royal Astronomical Society,' vol. v.

Among the cases recorded in the different catalogues, there are great numbers mentioned as attended by coruscations, flashes, and trains of various kinds, which can hardly be conceived otherwise than of an *electrical* nature. The serpentine or zigzag courses of many meteors recorded are incompatible with a solid body revolving in an orbit.

It has been noticed by Professor C. P. Smyth that the zodiacal light is slightly excentric with regard to the sun, so that the earth passes through its extremity once in its revolution, about Nov. 12.—[Edinb. Trans.]

Chladni conceives innumerable small bodies revolving in the solar system, and subject to the laws of gravitation. Messier, in 1777 (Memoirs of Royal Acad. Paris, 1777, p. 464), has recorded "Observation singulier d'une prodigieuse quantité de petites globules qui ont passé au devant du disque du soleil." Mr. Rumker has more recently recalled the attention of astronomers to the subject.

Some supposed analogous phenomena are not perhaps really entitled to be so considered; yet they tend to support the fact that diffuse matter of kinds little known may exist.

Such instances are those of dry fogs occasionally observed. The most remarkable on record is, perhaps, that of 1783; a remarkable year, in which, besides this phenomenon, there occurred a great volcanic eruption of Hecla, earthquakes in Calabria, and the passage of one of the largest and most remarkable meteors ever witnessed, and seen all over England.

The fog occurred over a great part of Europe, the north of Africa, and North America; but not in the middle of the Atlantic, perhaps owing to some current of the atmosphere which partially cleared it away. It continued more than a month. In some places it was observed to obscure or redden the sun; yet in general the stars were seen through it. It was accompanied by an unpleasant smell, was perfectly free from moisture, not affecting the hygrometer, and exhibited a *phosphorescence*.

It has been argued that its long continuance precludes the idea of its being the tail of a comet; but this is no proof that it might not have been a portion detached from such a nebulous mass, and retained by the earth till condensed or dissipated: whether it could be connected with the volcanic eruption, or with the meteor, remain questions open to speculation.

In 1831 a similar phenomenon was observed on the African coast, N. America, and Asia Minor, as well as in France and some other parts of Europe. The sun is said to have appeared *blue* through it; but the stars were occasionally obscured. These phenomena, however, *may* be purely terrestrial; as the Harmattan, or blowing of dust from the African deserts over the Atlantic, as well as the dust from volcanic eruptions, have been known to produce very similar effects.

In the catalogue originally given by Chladni (see Edinb. Phil. Journal, No. II.), largely confirmed by later instances, we find full verification of the fact, that meteoric matter has fallen of every degree of density, from the condition of almost pure metal to that of ore or oxide, more or less earthy, to matter of light, porous, soft or spongy nature, or even of the character of fine dust, or a dry fog or haze floating in the atmosphere: though it must be owned, the connexion of such phenomena as the last mentioned with those of meteoric masses may not be sufficiently proved.

[For some details in reference to this point, see Arago on the comet of 1833 (translation by Col. Gold); also 'Comptes Rendus,' 1847.]

The student should not overlook the ingenious conclusion of Sir H. Davy (Phil. Trans. 1817, Pt. I. p. 75), that the combustion of meteors must be that of solid matter, since combustion of elastic fluids could not be supported in so rarefied an atmosphere as exists at the great heights at which it occurs even in those instances which fall within the limits of our atmosphere.

One of the most instructive cases is that of a great meteor observed at the Cape of Good Hope (Phil. Trans. 1839, Part I.) which was seen to burn by daylight and to fall in portions, which were immediately collected and examined. The most considerable part of it is preserved in this country.

Those masses appear partially rounded, but broken in their fall, and of an earthy texture like baked clay, easily broken.

The meteorite which fell at Launton, 1840, preserved in the collection of Dr. Lee, at Hartwell House, is of a somewhat angular form, but having all its edges and corners rounded: an exact model of it exists in the Ashmolean Museum, Oxford.

No. 4.—Extract from the communication of Mr. F. Morton.—The August meteors at Wrottesley, 1859:—

"The display of meteors during the night was very grand. During an hour, from $1^h\ 10^m$ a.m. to $2^h\ 10^m$ a.m., 72 were counted in all parts of the heavens, the majority of which were followed by trains of sparks. The prevailing direction of their flight was towards the N.W. During the next half-hour at least 40 were seen, but the number was not accurately noted. A great number of those observed (from 25 to 30) were very fine, larger in fact than Capella or α Lyræ, which were then visible, several being larger than Venus when brightest. Though two observers were on the look-out together, no meteor was counted twice.

"Aug. 23, at $1^h\ 13^m$ a.m., the opening in the equatorial dome being E.S.E., a brilliant light was seen reflected from the western wall. This must have been caused by a very fine meteor, as the room was strongly illuminated at the time by the moon. Local mean solar time has been used throughout."

Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H. Hodgson, *Esq., late Resident in Nepal, &c. &c. By* Professor Owen, *F.R.S., Superintendent of the Natural History Departments in the British Museum.*

Mr. B. H. Hodgson, who has contributed an important element to the ancient history of India by his successful labours in unrolling the Buddhist records and deciphering the Buddhist inscriptions of Nepal*, has established an additional claim to the gratitude of the ethnologist by the assiduity with which he has collected the skulls of the various tribes or races of that part of the Indian continent.

This collection forms part of a still more extensive series of objects of Nepalese Natural History, contributed by the liberality of Mr. Hodgson to the National Collections.

The human crania, most of them adult, are upwards of 90 in number, and belong to the following

Tribes.

	No. of Skulls.		No. of Skulls.		No. of Skulls.
Newar	12	Uraon	3	Nepal (proper)	1
Lepcha	9	Shopa	2	Bengal (Fakir)	1
Bhotia	9	Sokpa	1	Ganges (man of the plains)	1
Murmi	7	Dimal	1	Lowlands (caste unknown)	10
Magar	5	Bodo	1		—
Sunwar	6	Kocch	2		90
Limbu	5	Khampa	1		
Kiranti	5	Bagnath	2		
Gurung	4	Hill-men	2		

* Journal of the Asiatic Society of Bengal, in the volume on General Subjects of Himalayan Ethnology.

Newar Tribe (12 skulls).

The general characters of the skulls of this tribe conform to those of the Indo-European type; but they are all slightly prognathous. They present a regularly-shaped fullish-oval cranium, showing varieties between the two extremes, as to length, of from 7 inches 6 lines (19·0) to 6 inches 4 lines (16·0)*, and, as to breadth, from 5 inches 8 lines (148·0) to 4 inches 11 lines (126·0); the broadest cranium being the shortest, viz. 16·0, the narrowest being the longest, viz. 19·0. The forehead is narrow, and, in most, low; but with well-marked varieties in this respect. The cheek-bones are rather prominent in a few skulls. The nasal bones show much variety, from great length and prominence to Æthiopian flatness. The supraciliary prominence is generally but little marked. The mentum is rather prominent, but short, except in two skulls, marked "from Saukhmol, Hill-man and woman." The frontal suture is obliterated, and the alisphenoids join the parietals, in all these crania.

The complexity of the sutural lines is various, being in most rather simple.

The broad cranium (1 x, x, x, x) belongs to the so-called 'brachycephalic' type; the narrow one (1 v, v, v, v) to the 'dolichocephalic' type. The average, which is also the common breadth, of the cranium, is 5 inches 3 lines (134·0).

Characters, Varieties, or Anomalies of Dentition.—In the Hill-man, the molar, m 1, has the enamel worn from the summit, and a smooth hollow of dentine is shown: p 4 and m 2 are partially worn, and p 3 and m 3 are slightly worn. In two skulls, the last molar, m 3, is not developed on either side of the mandible.

Lepcha Tribe (9 skulls).

The majority of these skulls show a greater prominence of the malar bones than in the Newar tribe; but whilst one Lepcha ($b. e, e, e, e$) exhibits a beautiful Indo-European form, another (1 a, a, a, a) closely resembles or repeats the Australo-Papuan type of cranium. The differences, as to length of cranium, range from 7 inches 4 lines (186·0) to 6 inches 4 lines (162·0); in breadth, from 5 inches 8 lines (144·0) to 5 inches (128·0); the narrowest skull (1 a, a, a, a) here, also, being the longest. We have in this series of skulls both brachycephalic and dolichocephalic types strongly marked—most of them having crania rather of the shorter than the longer oval, when viewed from above. All are more or less prognathous; those being least so which have least prominent malar bones. The chin is prominent in all. The nasal bones show the same range of variety as in the Newar tribe, ranging from prominence with compression and length, to breadth with shortness and flatness. There is more variety in the prominence of the frontal sinuses and superorbital ridges in the Lepcha than in the Newar tribe.

The frontal suture is obliterated, and the alisphenoids join the parietals, in all,—in one skull (1 c, c, c, c) by a mere point, in the rest broadly, as usual in Indo-European skulls. The forehead is rather low; is narrow in some: in one only is it broad in proportion to the cranium.

Anomalies of Dentition.—In one skull (1 y, y, y) m 3 is wanting in both jaws, in which m 1 and m 2 are worn, and there is no trace of loss of m 3. In another (1 d, d, d, d), the left p 4, upper jaw, is abnormally small.

Upon the whole, these Lepcha skulls are to be referred to a low, uneducated, and undersized family of the Indo-European race; but one (1 z, z, z) approaches the Æthiopian type, another (1 a, a, a, a) the Australian type;

* French decimal system.

whilst a third (*b. e, e, e, e*) shows almost the Greek model, save in a slight prognathism.

BHOTIA TRIBE (9 skulls).

In the nine skulls of this tribe it is instructive to find, as in the two former tribes, both the brachy- and dolicho-cephalic proportions exhibited. The extremes of length range from 7 inches (177·0) to 6 inches 3 lines (160·0); those of breadth from 5 inches 8 lines (144·0) to 5 inches 1 line (130·0); the broadest skull here, also, being the shortest. Save in two instances, apparently females, the malars are large and prominent, and the general aspect of the skulls is rather that of a Mongolian than Indo-European type. The former is very strongly manifested in a skull (1 *q, q, q*) marked "Inu Bhotia trans nivem"; and also in a "Sharpa Bhotia" (1 *z, z, z, z*), which shows the shortness and breadth of cranium, which has been ascribed by Blumenbach to the 'Turkoman's,' skull. In the Inu Bhotia the frontal suture is persistent, and the interorbital space is very broad: the muscular insertions on the occiput are strongly marked. All the Bhotias are prognathous; and, in all, the chin is prominent. The nasal bones are the seat of the same kind and range of variety as in the preceding tribes. In all the skulls the alisphenoids join the parietals, but with variable proportions—from two-thirds of an inch to a mere point.

Dental anomalies.—*m* 3, on the left side of the mandible, has protruded by the side, instead of the summit, of its crown.

MURMI TRIBE (7 skulls).

This series includes two certified female skulls and one skull of a child. One of the male skulls is more prognathous than in the previous races: in this respect the maxillary characters are those of the Æthiopian; but they are combined with a vertical forehead, with well-developed nasals, and with moderate malar bones: the cranium shows the Caucasian oval form: the alisphenoid joins the parietal by a suture of one inch in extent. The other male skulls are less prognathous and in various degrees: two of them show prominent malars: the nasals vary from extreme prominence (*l. i, i, i, i*) to flatness (*l. m, m, m, m*). The forehead is low in most, and is narrow in all. There is as much variety in the proportions of cranial length to breadth, in regard to the number of skulls, as in the foregoing series. The longest skull is 7 inches 3 lines (182·0); the shortest measures 6 inches 3 lines (158·0): the broadest is 5 inches 5 lines (137·0); the narrowest is 4 inches 10 lines (123·0): the shortness being more or less compensated by breadth, and *vice versâ.* In all the seven skulls the alisphenoids join the parietals, and the frontal suture is obliterated. These skulls show much variety in regard to the complexity of the cranial sutures.

MAGAR TRIBE (5 skulls).

Of this tribe, three skulls are of males, and show a longer form of cranium, with larger and more robust general proportions, than in the Murmi tribe. The length, in the three males, ranges from 6 inches 8 lines (166·0) to 7 inches 5 lines (188·0); the breadth from 5 inches (122·0) (in two) to 5 inches $3\frac{1}{2}$ lines (135·0). In two skulls the malars are prominent: in all the upper jaw is prognathous, and the lower jaw has a prominent mentum. The nasal bones are generally prominent. The occipital half of the cranium is unsymmetrical in one skull (*l. u, u, u, u, u*), which also shows a large foramen jugulare on the more prominent side. The alisphenoids join the parietals, and the frontal bone is single, in all the seven Magar skulls.

Sunwar Tribe (6 skulls).

Four out of the six skulls of this tribe show the broad and short or rounded form of cranium; a fifth would be classed as dolichocephalic; the sixth shows an intermediate type. The upper jaw is short, broad, slightly prognathous; the mentum moderately prominent; the malars prominent in all: upon the whole, the Mongolian or Turkoman type prevails in this series of Sunwar skulls. The dolichognathous skull (*l. o, o, o, o, o*) measures, in length, 7 inches 4 lines (186·0); in breadth, 5 inches $1\frac{1}{2}$ line (131·0): the average length of the four brachycephalic skulls is 6 inches 5 lines (167·0); the average breadth is 5 inches 9 lines (145·0). In all the skulls the alisphenoids broadly join the parietals, and the frontal suture is obliterated; the nasals vary from prominence to flatness.

Limbu Tribe (5 skulls).

These skulls exhibit a great range of variety: the one marked "*l.x,x,x,x,x*," in the oval contour of the cranium and face, in the delicate, almost vertical malars, in the form of the maxillaries, and in the development of the nasals, conforms to the Caucasian type; but although the forehead has proportionally a good shape and development, the capacity of the cranium is small. The skull marked "1 *v, v, v, v, v*," in the narrow and elongate form of the cranium, in the flatness of the nasals, in the projection of the broad jaws, and divergence of the malars, exemplifies the Negro type of skull. The length of this cranium is 7 inches 3 lines (185·0); its breadth is 5 inches $4\frac{1}{2}$ lines (136·0). The skull marked "1 *z, z, z, z, z*," combining a broad rounded form of cranium with a broad malar region, and a broad, short, yet somewhat prognathous upper jaw, conforms to the Mongolian type. The same type, with a somewhat longer form of skull, predominates in No. 1 *w, w, w, w, w*, in which the length of the cranium is 6 inches 5 lines (168·0), and the breadth is 5 inches $8\frac{1}{2}$ lines (145·0). In all these skulls the alisphenoids join the parietals, and the frontal is undivided. The same range of variation in the development of the nasal bones prevails as in the preceding series.

The principal anomalies shown in this series are the anchylosis of the atlas to the occiput in 1 *y, y, y, y, y*, leaving only the left neurapophysis, behind the condyle, free; this is separated from the right neurapophysis by an interval of 7 lines: the right posterior zygapophysis is double the size of the left one, and is convex: the nasal spine of the premaxillaries is much produced. In the skull marked "1 *w, w, w, w, w*," the upper or interparietal part of the 'squama occipitalis' is formed by three large 'wormian bones.'

Kiranti Tribe (5 skulls).

The same exemplification of both Caucasian and Mongolian types is given by this as by the preceding series of five skulls; but no Kiranti skull shows the simious combined with other Æthiopian characters: the nasal bones in all are prominent and well-developed. The oval or elongate form of cranium prevails, with a moderately prognathous jaw. In three of the skulls the malar bones project outwards. The chin is well-marked. The length of the cranium varies little, the average being 6 inches 10 lines (174·0); the breadth varies from 4 inches 9 lines (120·0) to 5 inches 5 lines (138·0). In all the skulls the alisphenoids join the parietals, and the frontal is undivided.

Anomalies.—One skull (1 *a, a, a, a, a, a*) shows a wormian bone in the sagittal suture, and a pair of well-marked 'paroccipital' processes: the skull (1 *b, b, b, b, b, b*) shows a mal-position of *m* 3 on both sides of the upper jaw.

Gurung Tribe (4 skulls).

The Gurung tribe is exemplified by one skull of an adult male, and by three skulls of boys, in which the dentition has not gone beyond the acquisition of the first true molar, with the deciduous series. These skulls show a slight family likeness in the degree of flatness of the nasal bones, with a slight general prominence of the interorbital region, and a moderate prognathism. In the adult male the forehead passes without indent into the nose, as in the Grecian type. The frontal suture is persistent; but it has been obliterated in the younger skulls. In the skull of the youth (1 *g*, *g*, *g*, *g*, *g*, *g*), on the right side, the frontal joins the squamosal; on the left side a wormian intervenes between the alisphenoid and parietal: in the others the usual junction of these bones obtains. The chin is prominent in all. The length of the adult skull is 7 inches (178·0); its breadth is 5 inches 8 lines (145·0). In this skull the squamosals are abruptly prominent below the parietals, and a great part of the suture between the ex- and super-occipitals remains. The following are the dimensions of three of these skulls :—

Gurung : males.	Adult.			Youth. Deciduous & *m* 1.			Child. Deciduous.		
	in.	lines.	mil.	n.	lines.	mil.	in.	lines.	mil.
Length of cranium ...	7	0	(178·0)	6	5	(163·0)	5	7	(144·0)
Breadth of cranium...	5	8	(145·0)	5	6½	(140·0)	5	1½	(130·0)

Anomalies.—In the boy's skull (1 *h*, *h*, *h*, *h*, *h*, *h*), with *m* 1 and the deciduous set of teeth, the right condyloid cup of the atlas has coalesced with the occipital condyle, and the rest of the atlas is so closely applied to the margin of the great foramen, as to indicate an ultimate, if not speedy coalescence of that part of the vertebra with the occipital one.

Uraon Tribe (2 skulls).

The skulls of this tribe are of adult males; they show a rather narrow elongate form of cranium, with prognathous maxillaries. In one the cheekbones project, in the other not. In both the nasals project and are short, with the usual indent between their root and the forehead. In the slightly larger skull the length of the cranium is 7 inches 1½ line (182·0); the breadth of ditto is 5 inches ½ line (130·0). The alisphenoids meet the parietals, and the frontal suture is obliterated, in both skulls.

Shopa or Sokpa Tribe (2 skulls).

The cranium in one of these skulls is short and broad, in the other it is long and narrow; the malars are somewhat prominent and the jaws slightly prognathous in both. In the dolichocephalic variety the length of the cranium is 7 inches 5 lines (188·0); its breadth is 5 inches 6 lines (140·0). The alisphenoids join the parietals, and the frontal suture is obliterated in both skulls.

Dimal Tribe.

The 'Dimal' skull most resembles those of the Gurung tribe, especially in the form of the interorbital part. This skull is chiefly remarkable as exemplifying the rare disease of hypertrophous thickening of the parietal bones.

Bodo Tribe.

This shows the dolichocephalic or elongate cranial form, with prognathous jaws and almost vertical, not projecting, malar bones. The nasals are slightly prominent, with a little depression between them and the forehead.

The length of this cranium is 7 inches 2 lines (184·0); its breadth is 5 inches 3 lines (135·0). The alisphenoids join the parietals, and the frontal is undivided.

Kocch Tribe.

Of the two skulls of this tribe, one shows the hypertrophy of the cranial vault to a great degree, with much density of the thickened bone. The other skull measures in length 7 inches 3 lines (185·0), and in breadth 5 inches (127·0). Both are prognathous, and the malars are slightly prominent: in one skull the nasal bones project, in the other they are flat.

Khampa Tribe.

This skull shows large and prominent nasals, continued, without indent, from the frontal bone, slightly prominent malars and maxillaries, with a low and narrow forehead, and the following proportions of cranium:—length 6 inches 10 lines (175·0), breadth 5 inches 6 lines (140·0). The parietals join the alisphenoids, and the frontal is undivided.

Bagnath Tribe (Nepal proper) (2 skulls).

One of these skulls is of an adult, the other is of a child. The jaw, in the adult, is slightly prognathous; the malars are slightly inclined outward; the nasals are moderately prominent; the forehead is low and narrow. The length of the cranium is 7 inches (180 0); the breadth is 5 inches $6\frac{1}{2}$ lines (142·0). In other characters this skull resembles that of the Khampa tribe.

Symbhunath Tribe (Hill-man, probably Thibetan).

The two skulls so marked differ singularly in the development of the nasal bones: in one (1 *c*) they are very long and prominent; in the other (1 *d*) they are flat: in the simious variety the malar bones are broad and prominent, and the jaw is broad and prognathous, giving a Mongolian aspect to the skull; the other skull conforms to Blumenbach's Caucasian type. In the skull 1 *d*, the length of the cranium is 7 inches 1 line (180·0); the breadth is 5 inches 5 lines (137·0). The skull 1 *c* is about 3 lines shorter and 2 lines broader than the other. In both the frontal is undivided, and the alisphenoids join the parietals, the right alisphenoid in 1 *c* being divided into three wormian bones.

Bagnath Tribe (Nepal proper).

The adult skull so marked is prognathous, with a moderate development of the nasal bones, and divergence of the malars at their lower part. The length of the cranium is 7 inches 1 line (180·0); the breadth is 5 inches 6 lines (139·0). The alisphenoids join the parietals, and the frontal is undivided. In the child's skull the left squamosal sends forward a process dividing the alisphenoid from the parietals. The suture dividing the mastoid from the squamosal is retained.

Man of the Plains (Ganges: unknown tribe).

This skull is prognathous, but with a good nasal development; the malars are scarcely prominent. The length of the cranium is 7 inches 2 lines (183·0); the breadth is 5 inches (128·0). The alisphenoids join the parietals, and the frontal is undivided. This skull shows a strong occipital spine.

Fakir (Bengal Islamite).

This skull is prognathous, with a less nasal development, but yet good: a slight malar divarication, as if tending to the Mongolian type, with a low forehead. The length of the cranium is 7 inches (178·0); the breadth is 5 inches $3\frac{1}{2}$ lines (135·0).

Lowlanders (Caste unknown).

In the series of 10 skulls so marked is shown the same extreme variety in the development of the nasal bones as in the Newar, Lepcha, and Bhotia series; in a few they are as flat as in the West African Negro, and in a few they are very prominent. There is not the same range of variety in the shape of the cranium; it is moderately oval, with the forehead narrow, and low in most.

In three specimens the length of the cranium is 7 inches (178·0), the least length being 6 inches 5 lines (165·0); the extreme breadth is 5 inches 3 lines (135·0), and this occurs in one of the larger skulls (1 *c, c, c, c*). In this skull the frontal suture is persistent. All are more or less prognathous, but some of them less so than in the majority of the Nepal tribes.

A skull marked 'Tarai' (1 *k, k, k, k, k*) and another (1 *b, b, b, b, b*) show prominent or divergent malar bones: in the rest the Caucasian proportions of those bones prevail.

Three of the above series of skulls show a produced nasal spine of the premaxillary part of the upper jaw—peculiarly so in "1 *i, i, i, i, i*" along the whole extent of the median premaxillary suture. In one skull (1 *j, j, j, j, j*) the squamosals join the frontals; in the rest the ordinary junction of parietals and alisphenoids prevails. In the skull marked "1 *e, e, e, e, e*" there are two large lateral wormian bones, which form the sides of the interparietal half of the superoccipital element.

Observations.

The first general remark that is suggested by the series of 90 skulls above characterized is, that the size and capacity of the cranium, or in other words, the amount of brain, is not greater than that which is usually found in the uneducated and lowest class of day-labourers in this country and in Ireland; and that this low development of cranium is associated with more or less prognathism. In all, the general size of the molar teeth accords with that of the white, olive, yellow, and red races of mankind.

The next remark is suggested by the extent of variety which is displayed, not merely in the entire series, but in the particular tribes or families comprising it. The long, short and pyramidal, and vertically flattened, forms of cranium are severally exemplified; just as, in skulls from ancient British places of sepulture, some are found which, "from an unusual degree of narrowness of the calvarium and face, belong less obviously to the brachycephalic class than usual*," whilst others show the platycephalic or the acrocephalic form†. These results of the experienced craniological observers, Davis and Thurnam, concurring with my own, teach us how deceptive any single specimen of the skull of any one tribe would be if viewed and described as exemplifying the cranial type of such tribe or family; and it shows the value of such extensive collections as that made by the accomplished and indefatigable Resident at Nepal.

* Crania Britannica, 4to. Davis and Thurnam, 6, 7 (7).

† Ibid. 12 (4) "In this stone barrow, on Wetton Hill, presenting only rude flint instruments, British pottery, the primitive flexed position of the skeleton, and the short rude cist —therefore with every mark of the primeval period, and no element of remote antiquity wanting—we meet with two separate and distinct aberrant forms of skull in interments of the same age."

There are not more than two or three skulls in the entire series which would have suggested, had they been presented to observation without previous knowledge of their country, that they belonged to any primary division of Human kind distinct from that usually characterized by craniologists as Caucasian or Indo-European: the majority might have been obtained from grave-yards in London, Edinburgh, or Dublin, and have indicated a low condition of the Caucasian race.

Only with regard to the Bhotias, a mountain-race, one of which was marked 'trans nivem,' could the Mongolian type be said to prevail. Where the skulls of any one of the Nepal tribes amount to from 6 to 10 in number, they present varieties in the proportion of length and breadth of cranium, in the development of the nasal bones, in the divarication or prominence of the malar bones, in the shape of the forehead, in the degree of prominence of the frontal sinuses, and projection of the supraciliary ridge, which would be found, perhaps, in as many promiscuously collected skulls of the operatives of any of our large manufacturing towns, and which would be associated with corresponding diversities of features and physiognomy.

As my experience in the characters of human skulls has increased, so has my difficulty of determining therefrom the primary race or variety of mankind. I have examined skulls of white Europeans, showing, as strongly as some of the Nepalese skulls, the flat nose, prognathous jaws, and contracted cranium of the Ethiopian. Only with regard to the Australian and Tasmanian aborigines do I feel any confidence of being able to detect, in any single skull, offered without comment to scrutiny, the distinctive characters of a race. The contracted cranium, flat nose, prominent jaws, and more or less protuberant cheek-bones are associated, in the Australo-Tasmanian race, with a peculiarly prominent supraciliary ridge and deep indent between its mid-part and the root of the nose; and still more peculiar and characteristic is the large proportional size of the teeth, especially of the true molars.

Upon what, it may be asked, does so close a conformity of character depend, which inspires confidence in the determination of race, by inspection of any single skull of the aborigines of the vast Australian continent and adjacent islands? It is probable that it depends on the degree of uniformity of the manner of life and the few and simple wants of those aborigines. The food, the mode of obtaining it, the bodily actions, muscular exertions, and mental efforts stimulating and guiding such actions, vary but little in the different individuals. The prevailing simple and low social state, the concomitant sameness and contracted range of ideas—in short, the small extent of variety in the whole series of living phenomena from the cradle to the grave of a human family of that grade, govern, as it seems to me, the conformity of the cranial organization.

In the woolly-haired Negroes of Africa there is greater range of variety of cranial organization, concomitant with a greater range of variety in their modes of life and physical development. I believe it would be rash to pronounce on the Negro nature of any single skull, save of some of the lowest races of the west coast of Africa; because I have observed, previous to the present craniological comparison, that the assigned characters of the Æthiopian cranium occasionally occur as fully developed in certain low individuals of other races; the subjects of the present Report afford similar instances. This experience has led to the inference that, in the ratio of the complexity of the social system, and of the diversity in the modes of sustaining life and spending it, is the range of diversity of feature and of cranial organization.

It is probable, therefore, from the effects of civilization and social progress in other varieties or families of mankind, that were the seeds of such progress to germinate and take on growth in the Australian family, the uniformity of cranial character now prevailing would be concomitantly and progressively modified. It is certain that such modifications of cranial structure and feature, accompanying diversities in modes of life, detract from their value as distinctive natural-history characters of races of mankind.

Supposing social progress to be possible in a race like the Australians, without admixture of other blood, a question of much interest suggests itself—in what degree and in what way the cranial physiognomy would be modified? By analogy I think it probable that the modification might, in the course of time, become at least as great as that which is observable in unmixed Negro races which for generations have been subjected to, and improved by, civilizing influences.

Upon the whole, then, in regard to the immediate subject of the present Report, undertaken at the request of the Committee of the Ethnological Section, and performed on that account, as well as out of regard for my accomplished and scientific friend Mr. Hodgson, with much pleasure and the best of my leisure and ability, I must confess that the results are rather negative than positive; but if they should suggest any improved views in the study and application of the physical characters of Man, the aim of the Section will not wholly have been unfulfilled.

Report of the Committee, consisting of Messrs. Maskelyne, Hadow, Hardwich, *and* Llewelyn, *on the Present State of our Knowledge regarding the Photographic Image.*

The chemical problem presented by the photographic image is one of great complexity. It is uninviting to the chemist in so far as it presents very little opportunity of his obtaining quantitative results; for howsoever subtle and rapid be the chemical transformation effected by the light, it consists, in most cases, of a superficial change only, and defies even the delicate methods of the balance. In undertaking to collect what is known and to test the correctness of what has been published regarding this intricate problem, the Committee have proposed to themselves to deal first with the simplest transformations on which photographic processes are founded, and to pass on from these to the more complex.

Moreover they confine themselves to the photographic results obtained with the salts of silver, as these are the most employed, and because it is necessary to assign some limits to their inquiry.

If the salts of silver are the most remarkable for their susceptibility to photochemical change, one is naturally led to search first for the causes of this among those simpler compounds of the metal in which the transformation is not complicated by the secondary decompositions which might be expected to accompany it in the case of organic compounds. Yet among the inorganic compounds this susceptibility to photochemical decomposition is rare; and though not absolutely confined to one salt, the chloride of silver, that body exhibits the simplest and one of the best illustrations of it.

The chloride of silver, when perfectly pure, passes, on exposure to light, from its pure white through various stages of change in hue, in which blue is mixed with grey, until it finally reaches a deep slate-violet colour. Chlorine is evolved from the chloride; but the question which here meets us *in limine* is one which probably underlies the whole of the problem we have to consider, and consists in the chemical condition in which the silver remains after the light has completed the decomposition so far as it can go. Is the result a subchloride of silver? or are the chlorine and the silver completely dissevered, the gaseous element going away, and the metal remaining mixed with, or rather encrusting, particles of unaltered chloride?

Certainly the weight of authority is in favour of the latter view. Such, at least, is to be gathered from papers by Dr. Draper of New York*, by Mr. Guthrie†, and more recently from a series of papers by MM. Davanne and Girard, in France.

In the first two memoirs referred to, an allotropic state of the metallic silver is viewed as the only explanation of the reactions of the dark substance formed by the light. No chemist, however, has yet produced this substance in such a state of purity as to be able to subject it to an analysis; and the only arguments, therefore, which can be relied on in explanation of the change are such as make the fewest assumptions and put the least strain on the present experience of the chemist.

There have been many methods proposed for the production of a subchloride of silver by processes directly chemical. One of these consists in the suspension of silver leaf in a dilute solution of sesquichloride of iron, or of chloride of copper. But this experiment has been repeated by us, and we are compelled to look upon the purple-tinted product as chloride of silver accompanied by but a trace of a substance possessing a profoundly-colouring power, which, as will presently be explained, we believe to be a subchloride.

In order to produce this substance with at all events a greater approach to isolation, we endeavoured to avail ourselves of the possibility of a reaction between chlorhydric acid and the suboxide of silver, and with this view instituted many experiments for the production of this last body in a state of chemical purity. Memoirs devoted to the chemistry of the suboxide of silver are not rare. Professor Faraday ‡ showed that the deposit formed by the exposure to the air of an ammoniacal solution of oxide of silver, consists of a compound with a composition of 108 silver and 5·4 oxygen. This composition is incompatible with a formula Ag_2O (supposing oxide of silver to be AgO); but the physical characters of the body are interesting. It is grey, and by reflected light is seen to possess a strong lustre. By transmitted light a thin layer of it appears bright yellow.

Rose § has called attention to various other reactions in which suboxide of silver appears to be formed. Thus, if ammoniacal solution of nitrate of silver be added to protosulphate of iron, a deep and intensely colorific black precipitate is formed, consisting of a compound expressed by the formula Ag_2O, $2FeO$, Fe_2O_3. Similar or analogous products of different composition are formed by the use of salts of the manganous oxide, and by solutions of cobalt; but in all these cases the suboxide of silver is associated in combination with other bodies, and does not present itself in a state from which it would be easily convertible into a subchloride. Rose, indeed, has made one remark, in connexion with these researches, which has a significance of some value for the photographic chemist. He shows that, in the case of adding the acetate of silver to a protoacetate of iron, the precipitate presents the black tint and deeply colorific power which seem to characterize the compounds of the suboxide of silver. When the salts used, however, contain "strong" mineral acids, as when nitrate of silver and sulphate of iron are the mutual precipitants, the deposit is grey and metallic—the reduction of

* Phil. Mag. xiv. 322.

† Chem. Soc. Quart. Journ. x. 74.

‡ Quart. Journ. Sc. iv. 268.

§ Journ. Pract. Chem. lxxi. 215, 407 *et seq.*; see also Wöhler, Pogg. Ann. xli. 344.

the silver is, in short, complete. The significance of this fact we shall hereafter recall.

The processes which seemed to hold out the greatest prospect of success for the production in the first place of a suboxide, and subsequently of a subchloride, by the methods of the laboratory, and independently of the action of the light, were those afforded by the reduction* of the citrate of silver, and by the conversion of arsenite of silver† by the action of a caustic alkali into alkaline arseniate, accompanied by a reduction of the oxide of silver to a mixture of metallic silver and suboxide, thus:

$$3\,AgO\,As\,O_3 + 3Na\,O\,HO = 3Na\,O\,As\,O_5 + Ag_2\,O + Ag\ddagger.$$

Of the results yielded by the first of these, none were found that gave any promise at all satisfactory. Hydrogen was passed through citrate of silver suspended in hot water. The products, at first brown, and then black, and finally grey, were examined at various stages of their progress in coloration, citric acid being used as a solvent to remove the citrate and the oxide §, the residuary product being examined by treatment with dilute chlorhydric acid to convert it into chloride. The citric acid solution was found to contain nothing capable of reducing permanganate of potash, and must therefore have been free from suboxide. The result of treating the residue with chlorhydric acid, and then dissolving the silver by dilute nitric acid, was a rose-tinted chloride of silver.

On the supposition that this residue was a mixture of suboxide, or a salt of it, with metallic silver, we are constrained to the view that the suboxide of silver is not characterized by the property of entirely passing, under the influence of chlorhydric acid, into subchloride. This seems to be confirmed in some degree by the results with the arsenite, to which we now proceed. To that reaction, which Wöhler has described, much attention was devoted; and it was tried under several modifications ||. By forming a dilute solution

* Wöhler, Ann. Pharm. xxx. 3.

† Wöhler, Ann. Chem. Pharm. cl. 363.

‡ The formula for arsenite of silver usually accepted is $2AgO\,AsO_3$, but we find Wöhler's formula as above given to be the correct one.

§ The brown product became converted into the black one by the treatment with citric acid. Both underwent similar changes under the successive action of chlorhydric and nitric acids, and both previous to this treatment reduced the permanganate of potash powerfully. But it was found that the citric acid alone was capable of reducing the deposit to the grey condition of metallic silver, withdrawing from it at the same time (all the) oxide of silver,—a result which seemed to render almost hopeless the effort to form the suboxide by its means.

Indeed the mere boiling of the citrate blackened it, producing a dark-coloured mixture of silver with some compound of the suboxide, the citrate itself undergoing a transformation which must have lowered its saturating power, as the solution remained neutral. The citrate, however, when thus boiled with water through which a stream of hydrogen was passing, became more darkly coloured, but imparted an acid reaction to the water.

The black body that results from the reactions described, contains organic matter, as it intumesces when heated. It cannot therefore be merely a mixture of metallic silver with the suboxide.

The dry citrate heated in a stream of hydrogen is very slowly affected at 212°, but passes at length into a substance which produces on the one hand a dark-brown solution, and on the other a brown residue which yields a very pale-red body on being transformed by chlorhydric and nitric acids.

|| It appeared, in trying Wöhler's experiment in several ways, that on the one hand it was extremely difficult to get rid of all the arsenic compound from the residue, and on the other that the tendency of arsenic acid in solution was to further the breaking up of the suboxide into oxide and metal. Lime- and baryta-water were therefore substituted for the soda, but still arsenite of silver remained undecomposed. This seemed due to its solid condition. It was to overcome this that the solution in nitric acid was adopted.

It was found, however, that the chocolate-tinted compound of chlorine and silver, by whatever process it had been produced, became, by fresh treatment with chlorhydric acid, again of arsenite of silver in nitric acid, and adding this very gradually to a boiling concentrated solution of soda, an extremely black powder was produced. This on being treated with dilute chlorhydric acid becomes grey; and on boiling the washed product with dilute nitric acid, silver is dissolved, and there is left a substance, which, if Wöhler be right in calling the black powder suboxide of silver, we should expect to contain subchloride of silver. The colour of this substance is a rich chocolate or maroon, more or less dark, according to the nature of the process: it never reached the deep slate-violet of the chloride of silver exposed to sunlight. On analysis it was found to contain as large an amount as 24 per cent. of chlorine;

The pure chloride $Ag\ Cl$ contains 24·74 of chlorine;
The subchloride $Ag_2\ Cl$ requires 14·08 of chlorine.

Other products of less-deep hue than the one first examined gave the numbers 24·3 and 24·2 per cent. of chlorine. Assuming that the chocolate hue was imparted to the substance by a subchloride (and no other view seems equally probable), we are constrained to recognize in this subchloride, only present to the amount at the furthest of 5 per cent., a surprising colorific energy.

From the experiments previously cited, we are disposed to think that our failure in this attempt to produce the pure subchloride of silver arose from the fact of the action of chlorhydric acid upon the suboxide of silver not being so simple as a complete conversion into subchloride would indicate; and we are the more induced to draw this conclusion from the analogy of the suboxide of mercury. Thus, if from a solution of the suboxide of mercury that oxide be precipitated, the action of chlorhydric acid on the precipitate is not to form the subchloride, but a grey mixture of chloride and metallic mercury. The same may perhaps apply to suboxide of silver; and, if so, it would be decomposed by chlorhydric acid, either partially or entirely, and would form chloride of silver and metallic silver.

One experiment we tried, in the hope of producing the subchloride of silver by a direct reaction. Chloride of silver is soluble in concentrated and highly alkaline arsenite of soda; and this solution, in the presence of excess of soda, was gently warmed. A brilliant mirror-like deposit, not of subchloride, but of metallic silver, was the result.

But with however little success the efforts to produce a pure subchloride of silver have as yet been crowned, the experiments we have detailed enabled us to institute a few comparative reactions whereby the result of treating a true subchloride (however diluted, so to say, with protochloride) with the ordinary reagents employed by the photographist may be achieved. The results yielded by these reagents were the following:—

Nitric acid, of sufficient strength to dissolve silver by heat, does not alter this dark compound.

Chlorhydric acid does not, when dilute, produce any apparent change in it.

Ammonia breaks it up entirely, dissolving all as chloride, except a minute amount of metallic silver, which remains.

Hyposulphite of Soda dissolves all except a trace of metallic silver like that left by the ammonia.

It will hardly be worth while to go through the reactions exhibited by

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capable of yielding a solution of silver when treated by nitric acid. So utterly unstable are these subcompounds of that metal!

Indeed it would seem that to secure to them any permanence, they must be formed in combination.

these several tests with the dark body formed by the photochemical decomposition of the chloride of silver, or of this body mixed with excess of nitrate; for we find that these reactions are in the several cases identical. The light-darkened chloride indeed presents a deeper and bluer colour than that formed artificially; but when it is considered that the light-formed body is a coating of uniformly and completely transformed substance—superficial it is true, but continuous in its surface—while the laboratory product is an intimate mixture of discontinuous particles, the bluer tint of the one and the redder tint of the other will hardly carry much weight in deciding against the identity of the colorific silver-compound in each case. Nor will it perhaps be considered to support the view of the photochemical reduction consisting in the complete severance of the metallic silver, that the product of that reduction can be formed by the light in the presence of nitric acid. The production of an allotropic form of silver in the nascent state, in the presence of nitric acid, seems certainly to make a larger demand on the credulity of the chemist than the assertion that the reduction stops at an intermediate stage, at which a subchloride is the result of it—a subchloride, whose properties we have seen to be identical with those of a substance formed in the laboratory, and to which it is difficult to assign any other composition than that of a subchloride of silver.

In the photographic processes in which the chloride of silver is employed, it is to be borne in mind that the chloride of silver is not used by itself—nay, by itself is quite inadequate to the production of the deep colour requisite for photographic effects. It is used in fact always in conjunction with nitrate of silver, and also, it must be added, with organic substances, among which the cellulose of the paper and the glue-like size are prominent. The action of the nitrate of silver needs little explanation; it supplies continually a fresh surface of chloride of silver, formed by part of the chlorine given off from the surface of the original chloride, which unites at once with the silver of the nitrates, and simultaneously becomes blackened by the action of the light. It is singular, however, that it has escaped the observation of the chemists who have experimented on this point, that an oxide of chlorine is also formed at the same time, as may be shown by the renewed deposit of chloride of silver which is produced in the supernatant nitrate by the addition to it of sulphurous acid. That the darker compound produced by the presence of nitrate of silver is in no respect different, save that it is a more abundant deposit, from that formed from the chloride alone, is evidenced by the identity of its reactions with those of the latter. For here, again, dilute nitric acid of sufficient strength to dissolve silver at 112°, is inert in its action on this bluish-black compound. Chlorhydric acid, if not sufficiently dilute, renders it somewhat paler, and gives a brownish hue to its slaty violet, but otherwise does not alter it. Hyposulphite of soda dissolves nearly the whole if sufficiently strong, leaving but a trace of metallic silver; and ammonia acts in a similar manner, while cyanide of potassium appears entirely to dissolve it.

In order to be satisfied that the bluish slate-coloured substance formed in the presence of nitrate of silver by the action of light on the chloride was not an oxychloride, an attempt was made to form such an oxychloride by operating on the chocolate-coloured substance so often alluded to. Boiled with caustic potash, this became dark brown; but nitric acid restored to it its chocolate tint. The substance operated on in this experiment was formed from the citrate by the action of hydrogen (in this case in the presence of nitrate of silver), and treatment of the products as before, by chlorhydric and nitric acids in succession.

We consider that we are justified in drawing the following conclusions:—

1. That the action of the light on chloride of silver is to reduce it, in so far as it is able to penetrate its substance, to the state of a subchloride.

2. That in the presence of nitrate of silver, this deposit of subchloride is necessarily more plentiful, while some part of the liberated chlorine passes into an oxide, which prevents a portion of the chlorine set free from conducing to the formation of fresh subchloride.

From this point we may proceed to the discussion of the photographic image in more complex, but, for the photographist, more available forms. And in doing so, we must at the outset bear in mind that the image varies in its character in different stages of the photographic process. The first result obtained by the light, even if it be the same in all stages of the solarization, is not the result which is in many cases left after the fixing solution has performed its work; but it is perhaps more interesting, as indicating the nature of the change effected by the light, independent of the chemical reagents which are afterwards applied.

In endeavouring to reduce into orderly arrangement the great number of photographic results which this inquiry involves, it seemed best to sever at the outset two series of them which bear but little relation to each other,—namely, the images obtained by development, and those which are formed visibly by the light. Commencing with the latter of these, the attention is at once arrested by the processes involving the use of chloride of silver in conjunction with the nitrate of that metal.

The rationale of the union of these two compounds for the production of an effect far greater than that upon the chloride alone, has been shown; but, practically, in photographic processes there are other agents present in the paper, or purposely introduced into it, which play a part in the photochemical change hardly less important than that of the silver salts themselves.—

We may fairly inquire in the first instance whether the presence of the fibre of the paper itself may not assist in effecting decompositions under the influence of light. To determine this point, Swedish filtering paper, as the type of the most uniform and pure fibre of paper that could be procured, was treated with nitrate of silver alone: on being exposed for some hours, it exhibited a pale-reddish stain, which after several days' insolation reached no deeper tone than a brown. The substitution of ammonio-nitrate of silver for the nitrate gave a rapidity to the change, and ultimately a depth of opacity to the result, by affording an antagonism, as we suppose, to the influence of the nitric acid. The reactions of the darkened ammonio-nitrate paper are as follows:—Ammonia does not otherwise affect it, than that treatment therewith (probably by action on the tissue of the paper) makes it slightly more readily acted on by other reagents. Nitric acid, though exceedingly dilute, rapidly dissolves it. Indeed an acid so far diluted that it took many hours to destroy the substance left by treating with ammonia Swedish paper that had been prepared with chloride of silver and subsequently darkened in the sun, was able to destroy this bronzed image formed by the ammonio-nitrate in a few minutes. Cyanide of potassium in presence of air rapidly destroys it, but not so rapidly as it does the image on chloride of silver just alluded to.

It would be difficult, from the above reactions, to come to any positive opinion on the nature of the photochemically changed substance left by the ammonio-nitrate of silver on pure tissue of paper. But that this tissue is not without a part to play in the changes which the oxide of silver undergoes, perhaps even a more important one than that of an absorber of oxygen, seems indicated by one curious experiment. Swedish filtering paper treated with nitrate of silver, and while still moist touched with a solution of protosulphate of iron, gives a grey stain easily recognized as metallic silver. When, however, it is suffered to dry (of course in the dark), the stain thus formed, instead of a grey, exhibits a dense black tone, which immediately afterwards passes on into a brown. The former of these is probably suboxide.

But if the tissue of the paper is not to be altogether excluded from the list of possible cooperative agents present in these processes, there are other substances of which the influence can be demonstrated in a manner quite satisfactory to the photographist. Gelatine as size was long employed without his being conscious of its importance; and he now uses albumen as a photographic glaze, and sometimes other substances, such as grape sugar, Iceland moss, caseine, &c., on account of the fine tones and permanence in the fixing bath which they impart to his pictures. Gelatine and albumen both combine with nitrate of silver; and the character of the combination is one which chemistry has yet to explain with completeness. These compounds differ from each other in many important respects: we shall select that with gelatine for illustration. The characters of the compound of gelatine and nitrate of silver are exhibited by the following statements.

If a sheet of transparent gelatine be floatedupon a solution of nitrate of silver, the solution loses a considerable amount of the dissolved salt. When the proportion of the gelatine to the bulk and strength of the solution is sufficient, free nitrate of silver is scarcely to be detected in the bath, and what silver is found there is probably in the form of a gelatine-compound, which is not entirely insoluble. The gelatine mass, though but slightly soluble in cold, is so to a considerable amount in hot water, and retains at once the neutrality and the taste of the nitrate. The solution gives the following reactions:—

Caustic potash throws down a bulky olive-brown precipitate, which clots into a tough extensile mass. This dissolves by boiling with excess of the precipitant, yielding a very dark, and when diluted, a clear yellowish-brown solution.

Strong ammonia produces no precipitate, but on boiling forms a pale orange-yellow solution, on which the light produces little or no change.

Chloride of ammonium, introduced cautiously, produces no precipitate, but in excess renders the solution turbid. The clear liquid is not rendered turbid by boiling; but a few drops of nitric acid, if the temperature be raised to the boiling point, suffice to render it milky from separation of chloride of silver, which may be redissolved by ammonia, or darkened by the light.

Iodide of potassium, unless carefully introduced, throws down a turbidity of a yellow tint, in it. But if this be removed by filtration, it will be found that the addition of the most dilute nitric acid and boiling throws down a fresh amount of iodide of silver.

Cold nitric acid produces no change in the gelatino-nitrate (?) of silver, even when formed from the ordinary commercial gelatine; but boiling throws down sometimes a small quantity of chloride, originating in the impurity of that body.

Chlorhydric acid in minute quantity produces also no precipitate until boiled, when the chloride of silver separates from the compound.

The gelatinous mass, formed by the action of the nitrate of silver solution upon the gelatine, becomes, on exposure to the sunlight, of a red colour. The change is a rapid one, and is accompanied by a shrinking of the mass to its original character of a thin sheet as it dries. The colour attained by prolonged solar influence is by transmitted light a deep ruby, and a "bronzed" green by reflected light. Sheets of the gelatino-nitrate of silver thus solarized no longer swell up or dissolve in boiling water, but only after long boiling become disintegrated in filmy fragments. Potash gives, on boiling, a clear solution, which even when dilute is brownish-red, and appears opaque when concentrated. Ammonia added to this liquid diminishes its opacity and gives it an orange hue.

In inquiring what the character of the change effected in these bodies is, we would direct attention to a process analogous to that by which the citrate of silver was examined. If hydrogen be freely passed over the albuminate of silver in a water bath, this becomes converted into a red body resembling in all essential particulars the red substance into which the light converts the same albuminate. In each case the reaction with the different tests is the same. That, in fact, a suboxide is in each case formed, and that this suboxide is in combination with the albuminous or gelatinous substance, seems the natural conclusion from what has preceded, no less than from the reactions of the bodies themselves.

The silver cannot be there in the metallic form; else, why should potash dissolve it, and why should ammonia convert it into a paler body? Moreover, metallic mercury does not amalgamate with it. One reaction, indeed, might be urged as militating against this view. The hyposulphite of soda has but little action on the red compound, whereas it dissevers the constituent elements of suboxide of silver as dissolved oxide of silver and residuary metal. But we have shown that silver is not entirely precipitated from its gelatinous nor from its albuminous compound by such tests as chlorides or iodides, and one will hardly therefore see with wonder that the albuminate or gelatinate of the suboxide resists the action of the alkaline hyposulphite. Nor would it be out of place here to hint, as our colleague Mr. Hardwich has done, at the high probability of the suboxide of silver associating itself with organic substances such as cellulose, albumen, gelatine, &c., in a manner analogous to that in which other metallic salts, in which the metallic element is not entirely saturated by metalloid elements, act the part of conjugate bodies, annexing themselves to the organic substances alluded to, and to colouring matters of various kinds. The action of these mordants belongs still to an obscure chapter of chemistry, but it is highly probable that the compounds under consideration are closely allied to them.

Finally, we have to bear in mind that the fixing agent modifies the image formed by the light in the materials we have been considering.

The alkaline hyposulphite, like ammonia, acts on the subchloride or the suboxide of silver, splitting the one into metallic silver and chloride which becomes dissolved, and the other into oxide and metal.

Obviously the conversion of an image formed of either of the intensely colorific subcompounds of silver into a pale metallic deposit containing only half the amount of metal, and possessing none of the remarkable colorific energy of the suboxide or subchloride, is a conversion that can only be expected to exhibit a great loss of tone. Practically the singular immunity from this dissevering action which the organic matter, combined with or conjugated to the subcompound of silver, extends to that subcompound, comes in to help the photographist from losing the beautiful result which the light itself produces. And what little he still must lose he can almost restore again by the remarkable toning methods which he has recourse to.

The rationale of these toning methods is to be sought in the chemistry of each different process. The deposit of gold from a solution of that metal is in its broad features a simple reaction—a deposit of a more electro-positive metal in substitution of one less so,—but the precise details of each method of using a gold toning-bath doubtless involve more refined chemical explanations. Without attempting to go into these, we would invite attention, however, to the sulphuretting baths by which this toning is sometimes conferred on the pictures. Sulphide of ammonium converts the fixed image on paper into, first, an intensely black compound, and subsequently, by its continued action, into a dull yellowish, scarcely visible stain. The latter, there can be little doubt, is sulphide of silver. It seems highly probable that the intermediate step in the process is the production of a subsulphide, and that it is at that stage that the progress of sulphurizing is arrested in a successfully-toned picture. This explanation would be quite in harmony with the conditions under which the toning is performed.

The results, then, at which we conceive that photographic chemistry may be said to have now arrived, in respect to the direct processes involving the use of silver-salts, may be thus stated.

The materials employed perform various functions:—

1st. One of these is that of supporting the picture, as a mechanical material or basis for holding the chemical bodies. Of the substances so employed the tissue of paper is one. Pyroxyline (the product of a substitution effected in the elements of the cellulose) is spread on glass to afford another. The latter appears to be inert. The former, on the other hand, seems to aid in the reduction, and possibly in some cases to remain in union with the reduced result.

2ndly. The silver-salts employed, whereof the chloride—for which may be substituted other salts, as the tribasic phosphate, the tartrate, the citrate, and many others, though each with a specific effect—appears to act by imparting *sensitiveness*. The nitrate, on the other hand, is present in excess to keep up a constant succession of sensitive material, and so to give *vigour* and *intensity* to the image.

3rdly. Gelatine as a size, or albumen as a glaze, and various other substitutes for these (though but little linked together by any chemical analogy amongst themselves), cooperate by conferring *rich tints* and deep tones, while they at once impart to the image formed on them an immunity from the destroying action of the fixing process, and form a mechanical surface more or less impenetrable, which prevents the other sensitive compounds from sinking into the paper.

Each of these substances can, provided nitrate of silver be present, be employed to produce an image. Thus, the chloride rapidly produces a faint picture; the "gelatino-nitrate" slowly yields an intense one; together they produce the required result. Whether that result is a cumulative one, the sum of the separate results, or a conjoint one produced by a combination of the chloride with the gelatine compound, it were difficult to say.

The image is, however, a mixed one, for treatment of it with dilute nitric acid leaves the slaty violet subchloride of silver. It seems therefore to be a mixture of subchloride with a gelatinous, and perhaps also a cellulose-compound of suboxide of silver.

The next great division of our subject which we have to enter upon is that of photographs produced by development.

Fortunately, in dealing with the images thus formed, we are able to dissever the results from the magic influence that calls them into being. We need only show that certain conditions are necessary for the impress of the invisible image; we are not called on to explain the character of the impress itself. Without attempting to explain what goes on in the camera obscura, we may determine the conditions for a favourable action in it, and interpret the results of that action after development; though even here, from the great delicacy of the processes employed, the task is a most difficult one.

With regard then, first, to the preparatory portion of these processes involving the production of the sensitive surface. This consists, in the processes on glass, in a supporting film, and generally in iodide of silver formed under conditions in which nitrate of silver was in excess. There are also generally present other ingredients, such as certain forms of organic matter, and in some cases bromide or even chloride of silver.

That it is not a matter of indifference whether the supporting basis, or film, consist of pyroxyline, or albumen, or gelatine, or of these severally combined with other bodies or with each other, one might readily suppose from what has been already said under the head of direct processes; and it will be no difficult matter to show more than a probability that this is not due to a "molecular," but to a "chemical" distinction in the action of these bodies.

The usual sensitive surface contains, if it does not consist in, iodide of silver with an excess of nitrate. But there are processes in which the plate is studiously washed with water to remove the nitrate, whereby, though it is impaired in sensitiveness, it retains enough of that quality for the production of excellent results. Though this retention of a susceptibility to the invisible impression has been attributed to mechanical causes, such as the state of division of the iodide, the porosity of the film, &c., the following facts seem to favour a chemical explanation. Pure pyroxyline united with pure iodide and nitrate of silver, from which the nitrate of silver has subsequently been removed, and the film dried, is not susceptible of quick development after exposure in the camera; a mere trace of albumen introduced before the removal of the soluble silver-salt, however, prevents its entirely losing this susceptibility. Gelatine, certain forms of sugar, resins, and various other bodies widely differing from one another in point of chemical character, possess a similar property, though the precise regulation of the processes employing them can hardly be said to be as yet mastered by the photographist. The products of decomposition contained in "old collodions," and some of the fresh preparations of pyroxyline, in which secondary products are not studiously prevented from being formed, would seem to share this power with the classes of bodies referred to.

But a question of the utmost interest to the scientific inquirer is involved in the chemistry of the iodide of silver; first, in respect to its power of forming combinations with the nitrate of silver, and secondly, as regards the probability of these combinations forming photographic compounds with the albuminous and other bodies alluded to.

That the excess of nitrate of silver which is necessary in the *first* preparation of all the sensitive films does not act the same part as that excess does in the case of the chloride in direct processes, will be evident at once, inasmuch as the iodide of silver does not undergo reduction in the manner that the chloride does. In searching, therefore, for an explanation of the necessity of free nitrate, the mind naturally dwells on the compounds shown by Schnauss* and A. Kremer† to be formed by the action of strong solution of nitrate of silver on the iodide. Although the production of these bodies in any quantity and in a state of chemical purity needs conditions not present on the photographic film, yet there seems little doubt that, as iodide of silver is dissolved by the nitrate, traces of these remarkable compounds can readily exist in the films containing these two ingredients. If so, the highly photographic character of the compound containing 2·8 per cent. of iodide of silver described by Kremer, and the fact of these bodies being decomposed with the separation of iodide of silver by the action of water, are facts of high interest to the photographic chemist, and seem to throw considerable light on the hitherto obscure processes in which iodide of silver is

* Archiv der Pharm. xcii. 260.

† Journ. für Prakt. Chem. lxxi. 54.

employed. These two facts, indeed, may be held to explain, very nearly, the character of the ordinary collodion process, but they do not explain the "preservative" processes in which the sensitiveness of the film is, within certain limits, retained by the introduction of albumen, gelatine, resin, sugars, or other organic substances, to the numbers of which experience is continually adding.

For the explanation of the action of these substances, we must recur to the facts already cited in the case of gelatine when used as a size in the direct processes. Thus, too, a plate coated in the ordinary manner with albumen containing iodide of potassium dissolved, will be found, on being raised from out of the silver-bath, not to be opake, and coated with a dense deposit of iodide of silver, but to appear highly translucent and opalescent in its character, and that, even though the iodide be introduced with a liberal hand. In fact, the albumen is present not merely as a mechanical vehicle for the sensitive materials, but can be proved to have combined with those materials, and to play no insignificant part in their photochemical transformation. That this is so, may be at once shown by adding some albumen to a quantity of the ordinary "silver-bath,"—say the white of one egg, diluted with $1\frac{1}{2}$ ounce of water, added to 40 ounces of bath. The iodide of silver with which the bath was previously saturated will be found in it no more; it is now to be looked for in the gelatinous precipitate which the albumen has formed. The precipitate is in fact a chemical compound of albumen with nitrate of silver holding in combination the iodide. This is, as might be supposed, from what has been said of the albuminate alone, a highly photographic compound. We have stated that a similar compound is formed by gelatino-nitrate of silver and iodide of silver. Citrate of silver, glycyrhizine, and many other bodies share with these substances, and the first two possess even in a far higher degree than they, the property of carrying down in a combination—or, so to say, in solid solution—the iodide of silver, and forming with it highly photographic products.

A hiatus must needs occur in this stage of our inquiry. The sensitive film is exposed in the camera, and in a few instants the invisible image is impressed. We remove it, and our task begins again at a tangible starting-point. The development of the image is the visible evidence that the light has been at work, and a close examination of the nature of this image is the only further key we possess to elucidate the character of the light's action.

By a comparison of the developed images formed on plates that have been exposed for the correct time to produce a good picture, with such as are produced by the direct action of the light, we arrive at two conclusions. First, a general similarity in the appearance of the various sorts of images by each method is observable; but, secondly, the deposit in the case of the developed image is far more abundant than that in the direct image. The comparison as regards the quantity of deposit in any two images is one far too delicate to be effected by the balance; but a method of instituting such a comparison with great accuracy is founded upon the ready conversion of any such images into sulphide of silver, a body transparent and yellow in thin layers, but passing through tones of sepia to almost a black opacity as the thickness is increased. The colour becomes thus a good means of comparing any two deposits, and the complete conversion of these into the sulphide is ensured by the use successively of chlorine-water and of sulphuretted hydrogen. A similar comparative result may be obtained by substituting the chloride of mercury for the chlorine-water.

Now the deposited images in the case of the processes by development present some points of great analogy to those formed in the direct processes;

in others these images widely diverge from them. Thus, we seldom find in them those purple and violet tones which seem to characterize the subchloride of silver before fixing. On the other hand, we observe two classes of developed images:—the one is of a dull metallic appearance, of a slaty grey character by transmitted light, and in but a feeble degree opake; the other varies in colour, exhibiting brown or red hues, and sometimes even presenting perfect opacity to transmitted light, closely similar to the picture formed by direct processes. But, on testing these two varieties of image by the method of conversion into sulphide of silver before described, it is found that the dull translucent metallic image teems with silver, and becomes very opake in the form of sulphide, while the more richly coloured and dense-seeming image loses opacity under the sulphurizing action, and exhibits at last a subdued tone of colour that brings it more on a par with the sulphuretted metallic image. Clearly then, here, density, and the qualities which give photographic value to an image, do not depend on the amount of metal that goes to form it, so much as on the chemical, and even perhaps mechanical state, in which that silver is present in it.

The several causes which determine the deposit of the images in these several states appear to be these:—

1. *The materials forming the sensitive film.*—Pyroxyline, in chemical purity, has little tendency to form the darker image. Albumen and the heterogeneous substances (including decomposed collodions), which we have had to yoke in the same class with it, have this tendency.

In general (speaking of the ordinary moist process) the tendency to produce the darker image is found to be in something like an inverse ratio, *cæteris paribus*, with the sensitiveness.

The use of the bromide of silver with the iodide imparts to a collodion film a tendency to deposit the grey metallic image, at the same time that a more powerful reducing agent is needed to develope it. It is a remarkable fact, bearing upon this singular property of bromide, that no compounds analogous to that formed by A. Kremer with the iodide have yet been formed with it. In the case of albumen, this influence of bromide is not felt; for with albumen, bromide of silver is held to increase the opacity of the image.

2. *The nature of the developing agent.*—The substances used to develope the latent image, besides the free nitrate of silver invariably necessary, embrace also without exception one ingredient, the character and the purpose of which is to reduce the salts of silver. In some cases organic bodies are employed for this purpose, in others the reducing agent is inorganic. Now, whether the grey or metallic form of image is completely reduced silver, and the more opake forms are an argentous compound (mixed or not with metallic silver), or whether all the forms of image are silver in different mechanical states of deposition, is a very important inquiry, and one on which the facts of the development and the nature of the developing agent may throw some light.

But no one who is intimate with the complex and perplexing details of this step in the photographic process will expect the chemist to come in and remove the difficulty by the use of a few formulæ. All we can hope to do is to point to a few sure results of experience, and indicate any explanation which may be suggested by facts from the laboratory analogous to these.

It is known, then, that to produce a "positive" picture in the camera, the developing agent should be sulphate of iron, acidified in some cases even by nitric acid. The result is the crystalline white deposit of metallic silver. Protonitrate of iron is used with a similar result. So likewise in the laboratory it is known that a neutral mixture of the ferrous sulphate and nitrate of silver forms the grey deposit, but that the addition of a little acid produces the white and brilliant form of the metal.

If now we would take a result opposite to this from the experience of the photographist, we may select an ordinary collodion plate prepared by the usual negative process, and we shall find that protacetate of iron developes the image of a black colour. Now Rose, in the remarkable experiments on the production of argentous compounds with the higher oxides of iron, &c., to which we have called attention, shows that whereas the argentic salts containing strong mineral acids are precipitated as grey metal by ferrous salts containing similar acids, the deposit formed by uniting the ferrous oxide and the argentic oxide, or the compounds of these with organic weak acids, contain the suboxide of silver and are black.

When to this is added the circumstance that the white and grey photographic images are with facility amalgamated with mercury, but that the coloured and black images are not, it may be treated as a matter of high probability that the black and coloured images are formed by compounds of the suboxide of silver.

A directive energy is exercised upon the nature of the deposit by the various kinds of organic matter employed in the development. These all seem to restrict the limits of variation to the dark bluish-black (given by citric acid when present), on the one hand, and various reds and browns upon the other; while, again, the presence of the albuminous and other substances, so often before referred to, is, as was above remarked, a sure means of forming these darker and coloured images. Indeed, albumen will determine such images notwithstanding that even free nitric acid be present with it. If it be a suboxide that causes the dark precipitate, that suboxide must go down in combination, and so resist the action of the fixing solvents.

But, 3. The character of the light has also a remarkable influence in inducing a grey or a dark character on the developed image.

If the picture has been produced by an intense light, as by a lens of large aperture, or as in the case of an exterior as contrasted with an interior view of a building, or as on a dull, misty day in contrast with a bright and sunny one, it will be found that, *cæteris paribus*, the tendency of the weaker action of the light is to allow the reduction of the silver in the metallic form. On the other hand, the more intense light has given to the molecules of the sensitive film a controlling energy which they exercise on the deposit, and which appears analogous to that of the light in the direct process, in its modifying the reduction and giving it the form of a production of an argentous compound; as though the iodic compound became in a certain sense phosphorescent to the chemical rays of the light, and operated on the mixed silver-salt and reducing agent as they float over it in the manner that the direct light might be supposed to do.

Of course, the materials must be nicely balanced, as regards their tendencies to produce the black or the grey images, for the peculiar action of an intense or a weak light to be made fully evident. Albumen or powerful organic agents will usually destroy this balance.

One fact remains to be observed. Whatever may have been the character of the first particles deposited on the plate, that character will be maintained thenceforward, and fresh deposits may be, so to say, piled upon the first by the singular agglutinative tendency of crystalline deposits, so long as the necessary conditions of fresh silver solution and of fresh stores of the reducing agent be supplied to keep up the action.

Our task has been, by an investigation of the chemistry of the image in its different varieties, to afford some data, at least, by which the further step may be hereafter taken of determining the precise character of the photochemical agency, to whose marvellous influences art owes so many beautiful results, and science is indebted for more than one intricate problem.

Report of the Belfast Dredging Committee for 1859. *By* GEORGE C. HYNDMAN, *President of the Belfast Natural History and Philosophical Society.*

THE Committee appointed at the Meeting of the British Association at Leeds, to proceed with the investigation of the Marine Zoology of the north and north-east of Ireland, consisted of Mr. Patterson, Dr. Dickie, Dr. Wyville Thomson, Mr. Waller, and Mr. Hyndman, who took measures to commence their operations early in June, from which time till the end of August various explorations were made along the coast and in the sea adjacent, extending from the south side of Belfast Bay (county Down) to the deep water north of the Maidens on a line with Glenarm (county Antrim).

Those acquainted with dredging operations will understand the difficulties and delays to which such work is liable, calms and storms equally interfering with progress. At the first meeting on the 7th of June, the weather was too fine to enable the party to reach the desired ground in due time; the few specimens of living Brachiopoda then obtained were forwarded to Mr. Hancock, who has been engaged in the investigation of that tribe, but owing to his absence from home the opportunity of seeing them alive was lost. On a second occasion, 22nd of June, the party engaged a steamer and succeeded in reaching the chosen ground for dredging in the deep water off the Maiden Islands, when a sudden storm arose, more violent than usual at that season, which obliged them to cease work and make for the shelter of land with all expedition, glad to save their ropes and dredges. A boat belonging to a ship of war then in Belfast Bay was not so fortunate, being upset in the squall, by which lamentable occurrence several men were drowned.

During the season the Committee were assisted by the co-operation of several gentlemen who took an interest in their work. In August, J. Gwyn Jeffreys, Esq., visited Belfast, and made one of a party for dredging off Larne, where a fortnight was spent in examining the coast and deep water adjacent, extending as far north as opposite to Glenarm. Mr. Jeffreys' experience and acuteness in discriminating species were of great service in adding to the lists and correcting some previous errors. During this period a steamer was again engaged from Belfast, which enabled a number of gentlemen to join in the labour and rendered good service.

It was originally contemplated to extend the investigation as far as Rathlin Island, but want of time and other circumstances prevented this from being accomplished.

Very comprehensive lists having been already published in the Reports of the British Association for 1857 and 1858, it is thought needless on the present occasion to do more than record such additions as have been made, with any further information that may be considered interesting regarding some particular species.

List of Species referred to in the Report of the Belfast Dredging Committee for 1859.

Philine quadrata, dead. In 80 fathoms off the Maidens.
Amphisphyra hyalina, dead. With the last.

Cylichna Lajonkaireana (Baster). From the Turbot-bank, dead; determined by Mr. Jeffreys in Mr. Hyndman's cabinet.
Mangelia attenuata, dead. Turbot-bank sand, Mr. Waller.
—— reticulata, dead. A single specimen of this rare and beautiful shell was found by Mr. Jeffreys in dredging from the deep water north of the Maidens. New to the Irish list. It is a southern form.
—— costata, var. coarctata, dead. Near the Turbot-bank.
Fusus Islandicus, var. gracilis (Alder), living. In 60 fathoms, about six miles from the Gobbins.
Buccinum undatum, var. striatum, Pennant; living. With the last.
Cerithiopsis pulchella, dead. In Turbot-bank sand, Mr. Waller; erroneously recorded in the list of 1857 as *Cerithium metula*.
Trichotropis borealis, living. Turbot-bank.
Lamellaria perspicua, living. In 80 fathoms north of the Maidens. This is usually a sub-littoral species.
Natica helicoides, dead. A single young specimen by Mr. Jeffreys.
Cerithium metula, of the list for 1857, was found by Mr. J. to be *Cerithiopsis pulchella*. In dredged sand, Turbot-bank.
Euomphalus (Omologyra) nitidissimus (Skenea nitidissima), living on *Zostera marina*. Shores of Larne Lough.
Skenea divisa, living. Off Larne, 1858, Mr. Hyndman.
—— planorbis, living. A small variety occurs in Larne Lough, has a more convex spire, and it appears to bear the same relation to the typical form that the *Helix rupestris* of Continental authors does to our *H. umbilicata*, Mr. Jeffreys.
Jeffreysia Gulsonæ, dead. Turbot-bank sand. In Mr. Hyndman's cabinet, determined by Mr. Jeffreys.
Lacuna crassior, living. Coast of Antrim. Mr. Jeffreys observed that the shell has a distinct canal or groove in the columella, evidently showing its generic position. The animal, which he examined, settles the question. It is of a yellowish white colour, having two subulate and slender tentacles, with the eyes placed on short peduncles at their external base; proboscis long and narrow; two rather long caudal filaments, one on each side of the operculigerous lobe. The creature is active in its habits, and seems fond of crawling out of water.
—— labiosa, Lovèn, dead. In Turbot-bank sand, Mr. Jeffreys.
Littorina fabalis, living. Found by Mr. Jeffreys on the shore of Larne Lough, and considered by him to be only a variety of *L. littoralis*.
—— tenebrosa, living. In the same locality as the last, and considered only a variety of *L. rudis*.
Scissurella crispata, dead. A fresh specimen taken in 80 fathoms, 5 or 6 miles north of the Maidens.
Margarita costulata (Skenea), dead. In Turbot-bank sand, Mr. Waller.
Trochus Montagui, living. An exquisite scalariform variety found by Mr. Jeffreys and Mr. Waller off the coast of Antrim; the animal does not differ from that of the usual form.
—— striatus, dead. In Turbot-bank sand, Mr. Jeffreys.
Emarginula reticulata, living. In 80 fathoms north of the Maidens. Mr. Jeffreys found the fry, which closely resembles a *Scissurella*, and has a regular Trochoidal spire, with the edges of the slit inflected.
Propilidium ancyloide, living. On stones and shells in 70 to 80 fathoms. They were of different sizes, the largest not exceeding one-eighth of an inch, and evidently adult. The *Patella cæca* of Müller, of which the authors of 'British Mollusca' supposed this might be the young, appears to be a very different species, if indeed it belongs to the same genus. (J. G. J.)
Patella athletica, living. Coast of Down, in Mr. Hyndman's cabinet.
Chiton cancellatus, living. Not uncommon in deep water.
—— Hanleyi. A fine living specimen on a shell, and one on a stone in 80 fathoms.
Argiope Cistellula, living. On stones as well as shells in the deeper water.
Terebratula capsula, living. With the last.
—— caput-serpentis, living. Of large size in the deep water. Some specimens kept living exhibited on the front margin a series of white filaments which appeared to protrude from the tubes of the shells, and not to be retractile when touched.
Pecten opercularis. Mr. Jeffreys remarks that the young have a rhomboidal form, and the lower or flat valve is much smaller than the other (which overlaps it), and is perfectly smooth. The ribs do not at first appear on the larger valve, but are preceded by a shagreened reticulation.
—— furtivus, alive. Taken in 1858 by Mr. Waller and Mr. Hyndman on both the Antrim

and Down coasts along with *P. striatus*. It was again taken this year, and at once distinguished by Mr. Jeffreys.

Pecten Danicus, dead. A single valve in 80 fathoms. In the former list, 1857, with a mark as being doubtful. This proves Dr. Dickie to have been correct.

Modiola modiolus, living. A small variety, three inches in length, occurs in deep water. The same at the Copelands. It is stated that specimens have been found on the West coast of Scotland, seven or eight inches long.

—— phaseolina, living. With the last in deep water.

Astarte compressa, dead. A few valves of the smooth variety, found by Mr. Jeffreys in the Turbot-bank sand.

Tellina pygmæa, dead. Valves united; from the Turbot-bank sand, in Mr. Hyndman's cabinet.

Solecurtus candidus, dead. In the Turbot-bank sand.

Sphænia Binghami, dead. Not uncommon in pieces of rolled chalk, and among the roots of *Laminaria digitata* by Mr. Grainger. Mr. Jeffreys doubts its having the power of burrowing or excavating. See Mr. Jeffreys' "Gleanings" in the 'Annals of Natural History' for Sept. 1859.

Mya truncata. A young living specimen was brought up by the dredge from 80 fathoms on stony ground; its usual habitat being low-water mark in mud.

Saxicava arctica, living. Not uncommon, moored in cavities or crevices of stones and shells. Mr. Jeffreys considers it to be merely a variety of *S. rugosa*, differing in habitat. The latter, when enclosed in stone, loses the sharp keel and teeth of *S. arctica*, and is more rugged in appearance.

Pholadidea papyracea, living. At a depth of 80 fathoms North of the Maidens, in small pieces of soft sandstone. The smaller specimens want the cup-shaped appendage, whether the effect of insufficient space or immature growth.

An examination of these smaller specimens affords means of correcting an error in the first list of 1857. The so-called *Pholas striata*, being identical with these, is therefore to be expunged.

Cynthia limacina, living. On stones and shells from deep water.

Balanus tulipa alba (Hameri of Darwin) is not uncommon, living in the deep water.

Balanus —— ? Of another species, not yet determined, a single dead specimen was found in 80 fathoms.

Sphænotrochus Wrightii. A few dead specimens were found in the Turbot-bank sand by Mr. Hyndman in 1852, and subsequently by Mr. Waller. Dr. Perceval Wright, having seen these specimens in Mr. Hyndman's collections, received permission to hand them over to Mr. Gosse, who has described and figured them in the 'Dublin Natural History Review' for April 1859.

Sagartia coccinea. A sea anemone appearing to be this species is not unfrequent on stones and shells from deep water.

Appendicularia flagellum. On the 7th of June, 1859, a bright calm day, this curious and interesting animal was seen in great abundance floating through the water at the northern entrance of Belfast Bay. It has not hitherto been recorded as Irish; but has been fully described by Professor Huxley in the 'Microscopic Journal,' vol. iv.

Sagitta bipunctata. Several specimens were taken in the towing net along with the former. Dr. Wyville Thomson had discovered it a short time previously in Strangford Lough. Not hitherto recorded as Irish ?. It has been described by Dr. Busk in the 'Microscopic Journal,' vol. iv.

Hippolyte spinus. In the deep water off the Maidens: determined by Dr. Kinahan. A Northern species, inhabiting the seas of Iceland and Greenland. New to the Irish list.

Acanthonotus testudo. Taken with the last.

A pleistocene bed of stratified gravel was observed on the side of the road between Larne and Glenarm, and was examined by Mr. Jeffreys and Mr. Hyndman. It was found to contain several species of shells, corresponding with those from a bed at the Belfast Water Works, recorded in Portlock's Report on the Geology of Londonderry.

The following is a List of the species obtained, which will no doubt be augmented on further investigation :—

Pholas crispata, fragments.
Tellina solidula.
—— calcarea (Möller).
Mactra subtruncata.
Astarte compressa, var. globosa.
Astarte elliptica.
Mytilus edulis, fragments.
Leda oblonga.
Hypothyris psittacea.
Turritella polaris (Möller).
Natica Montagui.
Natica clausa (nana Möller).
Buccinum undulatum (Möller).
Trophon clathratus.
Mangelia turricula.
—— Pingelii (Möller).
Balanus tulipa alba.

of this number, about one-half are found living on the coast, the other half belong to extinct species.

The existence of this bed of gravel with its fossils may hereafter serve to throw some light on the question of the presence of so many northern forms of shells on the Turbot Bank. As yet there is no evidence to forbid the conclusion that all such forms may be found alive in the sea not far distant. A large proportion of those known to be living is found scattered very sparingly; whilst others, whose existence in the living state admits of no doubt, have not yet been discovered in their haunts. Many species may be living close at hand in situations where the rocky nature of the ground, and the strength of the currents preclude the possibility of the dredge ever reaching them.

One interesting fact may be noticed connected with the distribution of animal life;—that there are several species, viz. three Neæras, two Astartes, and some others, existing in the Clyde, immediately opposite the deep-sea region north of the Maidens, where none of these species have been discovered; whilst in the latter locality, *Argiope*, *Terebratula capsula*, and *Pholadidea*, with perhaps others, are found living and not known to exist in the former locality. The region of the Clyde and that of the Maidens, though separated by a narrow sea, exhibit well-marked and distinctive peculiarities in their respective Faunas.

The Committee consider that their labours, under the liberal assistance of the British Association, have now come to a close, but much yet remains to be done to complete the List; still they hope that individuals may be found willing to continue the investigations, so as to carry out the wish expressed by Dr. Perceval Wright in his Report for 1858, that the results of the labours of the several dredging Committees may in a short time be united to form a complete Irish Marine Fauna.

Continuation of Report of the Progress of Steam Navigation at Hull. By JAMES OLDHAM, *Esq., Hull, M.I.C.E.*

IN continuation of my Report on the Progress of Steam Navigation as connected with the Port of Hull, I have to observe that, during the last two years, no very great change has taken place in the number of steamers, although I shall have to state some interesting facts occurring during that time. For generations past, Hull has been noted for its Greenland and Davis Straits Fishery, and for many years this constituted the chief feature of the port; and at one time upwards of sixty large ships were sent out with crews varying from thirty to forty men each, and representing a capital of all that concerned the trade of about £700,000 sterling. In 1818 Hull sent out to the fishery sixty-three ships which brought home 5817 tons of oil, and in 1820 sixty ships were sent out and returned with 7782 tons of oil, exclusive of whalebone. In this year (1820) the total number of ships at the fisheries from England and Scotland amounted to 156, and the entire weight of oil obtained was 18,725 tons, and of whalebone 902 tons.

Owing, however, to the introduction of coal-gas for the lighting of streets and buildings, and large importations of oils for manufacturing purposes from the Mediterranean and other places, together with the scarcity and difficulty of taking the whales, fish-oil became in a great measure superseded, and consequently the fishery nearly abandoned, and an enormous amount of property, once of so much value, almost entirely lost. Within the last two or three years, steam has been put into successful requisition to aid the dauntless and hardy mariner in the pursuit of this hazardous calling, and now we have several screw steam-ships employed; and although some of them are fitted with comparatively small power, they have proved to be possessed of great advantage in the service, and in some instances satisfactorily to the owners.

We have had two descriptions of steam-vessels employed in the fishery:—the first, the old wooden sailing ships which had been engaged in the service for some years, but which were afterwards fitted with screw machinery and auxiliary steam power; the second, iron-built ordinary screw steam-vessels, but which proved, I believe, almost a total failure; the material of which they were built, and the want of strength for such a purpose, proving them altogether unfit to contend with the severity of the climate and rough encounters with the burgs and fields of ice, some becoming total wrecks, while others returned bruised and rent, and with difficulty were kept from sinking. A question here arises, how far iron ships are calculated to bear the severe frosts of high latitudes? and whether wooden-built vessels, with all their defects, are not the best adapted for encountering such a climate? The screw steam-ship which was first sent from Hull or any other place to the fishery as an experiment, was the 'Diana,' timber-built, 355 tons and 40 horse-power, high pressure, the property of Messrs. Brown, Atkinson and Co., of Hull.

This vessel had been some time engaged in the fishery as a sailing ship; but her spirited owners, thinking an important advantage could be gained, determined upon the adoption of steam power, and at once had the 'Diana' fitted for the spring of 1857, by Messrs. C. and W. Earle, who put in the engines and made the screw to lift out in case of need.

The experiment fully answering their expectations, Messrs. Brown, Atkinson and Co. bought the 'Chase,' a fine American-built ship of immense strength, and of 558 tons. She was fitted by Messrs. Martin, Samuelson and Co., with condensing engines of 80 horse-power, and despatched to the fishery in the early part of 1858, and with good results.

By the application of steam, ships in this service can now make a voyage, first to Greenland, and afterwards to the Davis Straits.

In the commencement of this year several ordinary iron screw steamers were despatched to Greenland, viz. the 'Corkscrew,' 'Gertrude,' 'Emmeline,' and 'Labuan;' the latter only of this class, which is the property of Messrs. Bailey and Leetham, had any success, but in consequence of her great strength and peculiar form, succeeded in a tolerable way; the others were much damaged, and, as I have already remarked, returned in bad condition. The 'Labuan' is 584 tons burthen, and 80 horse-power.

The next point of interest connected with the steam-ships of the Port of Hull refers to alterations made in some of the vessels. The 'Emerald Isle,' a paddle timber-built ship of 1835, the property of Messrs. Gee and Co., originally $135\frac{8}{10}$ long, was lengthened 35 feet, with a gain of 14 inches draught of water, and an increased capacity for 100 tons dead weight. The 'Sultana,' iron screw steam-ship of 1855, the property of the same house, originally 150 feet, was lengthened 30 feet, with a gain of 10 inches draught of water, and an increased capacity of about 100 tons. It is interesting to observe that in both cases we have no diminution of speed through the water, and that both vessels are improved as sea-boats. Daily experience teaches the advantage gained, in almost every point of view, by ships of great comparative length.

The iron steam-ship 'Lion' of Hull, formerly a paddle-boat 249 feet long, but now converted into a screw steamer by her owners, Messrs. Brownlow, Lumsden and Co., under the direction of Mr. Anderson their engineer, exhibits the great advantage gained by the alteration. Her register tonnage is 690, and the total tonnage 1014. She was formerly fitted with steeple engines of 350 horse-power, and had four boilers, two before and two abaft the engines; but these were substituted by direct action engines of 150 horse-power, and two of her old boilers replaced, and by this alteration a clear length of hold in midships of 23 feet is gained. She required before the conversion 650 tons of coals for a Petersburg voyage, and consumed 30 to 40 cwt. per hour, but now 350 tons for the voyage, and a consumption of 20 cwt. per hour. By the change of machinery about 130 tons of dead weight is removed from the ship, and she is now able to carry 400 tons more cargo. Her speed is also improved considerably; for before the alteration, when drawing on an average about 14 feet, the rate was $6\frac{1}{2}$ knots; but since the change, when drawing even more water, they can steam 8 knots. Thus throughout a saving almost in all the departments of the ship, and other advantages have been effected in this important change.

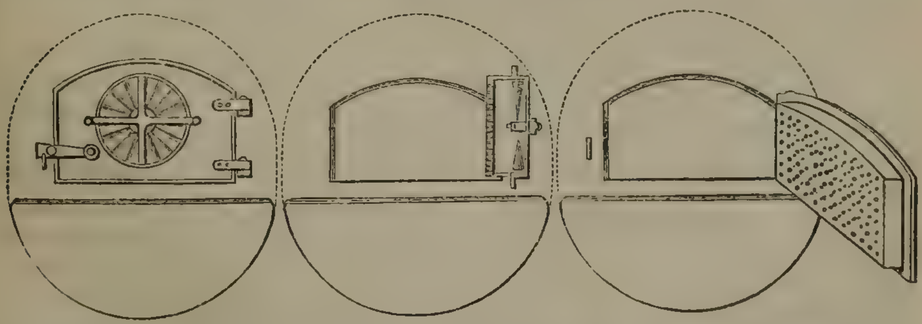
During the last two years many fine steam-ships have been built in Hull, and others are in process of building for English and foreign service, by Messrs. Brownlow, Lumsden and Co., Messrs. C. and W. Earle, and Messrs. Martin, Samuelson and Co.

The last-named firm are making rapid progress in the building of two large iron paddle steam-ships, for the Atlantic Royal Mail Steam Navigation Company, of the following dimensions, power, &c.:—

	feet.
Length between the perpendiculars........	360
Beam, moulded.........................	40
Depth	30
Tonnage, builders' measure..............	2860
Nominal horse-power	800

These ships are to have three decks, and to be fitted fore and aft for passengers. Speed through the water 20 miles per hour. They will be of immense strength, and their build and form such as to ensure their becoming fine sea-boats.

Since the Meeting of the British Association at Dublin, considerable advance has been made in London and other ports in the application of superheated steam, and I believe with great success and satisfaction in the results.



Hull, however, is acting on the motto *Festina lente*, and before taking a decided step in this important discovery, is anxious to see and adopt the best mode of the application of the principle, being assured that, in every onward movement, it is better to "make no more haste than good speed." Some attention has been paid to the consumption of smoke in the furnaces of our steam-vessels, and with a considerable amount of success. I may here mention the mode of Mr. Ralph Peacock, of New Holland, Hull, for which he has taken out a patent; it consists, as shown by the plan (No. 1), of a double furnace-door, the chamber or space between the inner and outer surfaces being 5 to 6 inches in width. The inner plate is perforated very full of small holes; and in the outer plate a revolving ventilator is inserted, which is on the principle of that invented by Dr. Hale, to supply close places with fresh air.

The apparatus is in use on board the 'Helen Macgregor,' one of Messrs. Gee and Company's large sea-going steam-ships, and has given very general satisfaction; for by the report of the Chief Engineer, Mr. M'Andrew, a saving of fuel is effected, and the steam better sustained. Another great advantage, as reported by the Master, Captain Knowles, derived from this invention, is that in running before the wind, they are never now annoyed and endangered by a dense cloud of smoke in the direction of the ship's course, which, particularly at night time, creates so much risk of collision. This apparatus is also in use on board several other steamers, viz. the 'Yarborough' and 'Grimsby,' belonging to the Anglo-French Company, the 'Alert' of Hull, and also a number of river steam-boats.

I have great pleasure also in noticing an improvement introduced on board the 'Queen of Scotland,' another ship belonging to Messrs. Gee and Co., for the same object, by the Chief Engineer, Mr. Smith, and having furnaces of ample capacity, answering the purpose in a most satisfactory manner. Mr. Smith's mode consists simply in keeping a few inches of the front ends of the bars quite clear and clean from side to side of each furnace; thus admitting at the right place a sufficient amount of air. The report of the Master, Captain Foster, is very satisfactory. I have witnessed also the effect of this mode in the furnaces of stationary boilers with perfect results.

I have now to refer to the application of Silver's Marine Governor (see Plan No. 2), as applied by Mr. John Hamilton of Glasgow. Several of these ingenious and efficient instruments are now in use on board steam-ships in the Port of Hull, giving the highest satisfaction. They are so sensitive in their action, that the slightest pitching motion is at once indicated, and the steam admitted or excluded as the case may be. By the use of this governor, the full power of the engines is in immediate and constant requisition, producing the effect of saving of time, saving of fuel, and preventing of accidents by what is termed racing, and otherwise. The ordinary mode in the absence of the governor, is for the engineer, in stormy weather and heavy seas, continually to stand at the throttle valves, or to save himself this trouble, to throttle the engines, and thereby, when the full power of the engines is most required, it is frequently reduced to one-half or less, and consequently there is occasioned a loss of time on the voyage, and a risk of falling on to a lee shore. The following is a brief statement of the tonnage, &c. of steam-vessels belonging to, or trading from, the Port of Hull at the present time:—

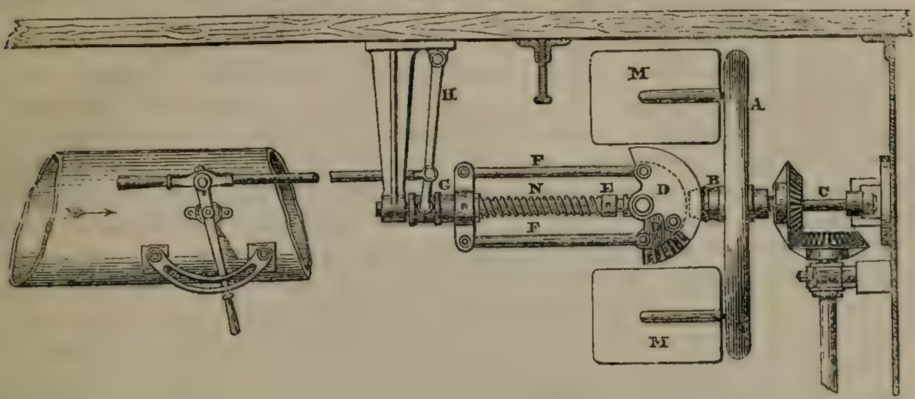
1st. Sea-going steamers belonging to the Port, 22,290 tons register; horse-power, 5824.

2nd. River steamers belonging to the Port, 1050 tons register; horse-power, 450.

3rd. Sea-going steamers trading to Hull, but belonging to other ports; and although many changes have taken place remaining much the same; as shown in my last Report, viz. about 21,200 tons register; horse-power, 5300.

4th. River steamers trading to Hull, but belonging to other places, 2450 tons register; horse-power, 1200.

The number and tonnage of sea-going steam-vessels belonging to Hull have increased since my last Report. The river steamers belonging to the Port remain nearly the same; this is also the case with sea-going and river boats belonging to other places, but trading to Hull.



Silver's Patent Marine and Stationary Engine Governors. Constructed by John Hamilton, Engineer, Glasgow.

The Engraving represents the Momentum Wheel Governor or "Nautical Regulator," as it is usually placed in the Engine-room of a Steam-Ship. It consists of a momentum wheel, A, fixed on the boss of a pinion, B, which works loosely on the spindle, C, and gears into the two-toothed sectors, D D. These two sectors being supported on a crosshead, E, made fast to and carried with the spindle, C, work in opposite directions on the pinion, B; and, as they are linked by the rods, F F, to the sliding collar, G, which receives and works the forked lever, H, communicate motion to the throttle valve. M M are vanes, and N is a spiral spring, both of which are adjustable.

The action of the above Instrument is as follows:—When the spindle of the Governor or "Nautical Regulator" is turned by the engine to which it is attached, the two-toothed sectors, which are carried on the fixed crosshead, being geared into the pinion on the momentum wheel, have the tendency to turn round on this pinion; but as they are linked to the sliding collar, they necessarily pull inwards this collar, and so compress the spiral spring; and this spring, reacting on the collar, and consequently on the toothed sectors, serves to turn round the momentum wheel, while the vanes on the momentum wheel balance the action of this spring by the resistance the atmosphere offers to their progress through it. As the leverage action of the toothed sectors upon the momentum wheel pinion increases, as the spring becomes distended, and *vice versâ*, it will be seen that the reaction of the spring in propelling the momentum wheel will at all times be uniform, and as much only is required as will carry round the momentum wheel with its vanes at its proper speed, and overcome the friction of working the throttle valve, and throttle valve connexions. When the momentum wheel is in motion, it will rotate with the engine to which it is attached, at a velocity proportioned to that at which it is fixed by the connecting gear; and while the engine from the usual causes may attempt to vary this velocity, it cannot affect the momentum wheel, but leaves it free to act upon the sliding collar, and consequently upon the throttle valve—at one time closing the throttle valve by its action in resisting any increase of velocity, and at another time opening the throttle valve by its action in resisting any decrease of velocity on the part of the engine. It will now be evident that the power of such a Governor or Regulator must be very great indeed, having for its agent a momentum wheel which may be increased to any dimensions; and from the powerful resisting tendency of such wheel, it necessarily follows that its sensitiveness of action must also be very great, and in exact proportion to the tendency of the engine to vary its speed; and the engine itself being the direct prime mover of the throttle valve, it also follows that the inert power of the momentum wheel increases its resistance exactly in proportion to the rapidity with which the engine varies its speed. Hence a momentum wheel of 2 feet 8 inches diameter, and 2 inches periphery, running at a speed of 180 revolutions per minute, is found to be sufficient to work with promptness and ease the largest throttle valve, and to equal the power of several men. Unlike the ordinary forms of Governors, it is entirely unaffected by changes of position, and therefore perfectly adapted for Marine and Portable, as well as Stationary Steam-Engines.

Mercantile Steam Transport Economy as affected by the Consumption of Coals. By CHARLES ATHERTON, *Chief Engineer, Royal Dockyard, Woolwich.*

PUBLIC usefulness, as dependent upon science, being the great object for which the "British Association for the Advancement of Science" was originated, and has now been signally upheld for twenty-nine years, a period remarkable for the progress that has been made in the utilization of the powers of nature, to such an extent that the international condition of the globe is now being revolutionized by the progressive practical utilization of elements which heretofore were regarded merely as phenomena of nature, viz. Steam and Electricity; in which revolution the application of steam to the purposes of navigation has played so conspicuous a part, that now, in proportion as steam may be effectively employed in the pursuits of commerce and of war, it is acknowledged that even nations will rise or fall; seeing, moreover, that at no period in the history of steam navigation has so great a step been made in its practical development as has recently been realized by the fearless introduction, in marine engineering, of the long known but neglected effects of increased pressure, superheating, and expansion; the recognition and application of which principles have now, at length, been attended with such effect in marine engineering, that the consumption of fuel with reference to power is now known to be practically reducible to less than one-half of the ordinary consumption of coal on board ship;—seeing also that mercantile enterprise, setting no limit to speculative investment, has in these days emancipated mechanical intellect from the restrictions by which ideas as respects magnitude have hitherto been bound;—under such circumstances I cannot doubt that any effort to popularise a knowledge of the practical utilization of steam, with reference to the consumption of fuel, though advanced with no pretensions to science, beyond that which may be awarded to originality and labour in the application of calculations to develope useful results, will be favourably received, more especially as the paper which I now beg to present is in continuation and conclusion of an inquiry, which has already, in part, on two occasions been favourably entertained by this Association, and honoured with a place in its published records. The former papers to which I allude are,—1st, "Mercantile Steam Transport Economy, with reference to Speed," vol. for 1856, p. 423; 2nd, "Mercantile Steam Transport Economy, with reference to the Magnitude of Ships, and their Proportions of Build," vol. for 1857, p. 112. And I now purpose to bring this inquiry to its conclusion by the following paper on—

Mercantile Steam Transport Economy, as affected by the Consumption of Coals.—My purpose, and the drift of my remarks will probably be the more readily understood by my at once adducing the following Tables C and D, and the diagram E, in continuation of the Tables A and B, which are published in the Volume of Reports for the year 1857, pp. 116 and 119, observing with reference to these Tables C and D, that the rate of consumption of coal on which the calculations are based, viz. $2\frac{1}{2}$ lbs. per indicated horse-power per hour, has been practically realized on continuous sea service, although the ordinary consumption of steam-ships in the Royal Navy, as well as in the best vessels of the most celebrated steam-shipping companies, is, I believe, at the present time fully 50 per cent. in excess of that amount; and I may say, that in steam shipping generally, the consumption of coals per knot of distance, with respect to displacement and speed, is double the consumption which these Tables, based as they are on an example of existing practice, show to be now practically realizable.

The Tables now adduced are as follow :—

TABLE C.—Calculated for the Speed of 10 knots per hour, and showing the mutual relations of Displacement, Power, and the Consumption of Coal, per Day, Hour, and Knot, the Coefficients of Dynamic performance, deduced from the Formula $\frac{V^3 D^{\frac{2}{3}}}{\text{Ind. h. p.}}$, being assumed to be 250, and the consumption of fuel at the rate of $2\frac{1}{2}$ lbs. per Ind. h. p. per hour.

TABLE C.

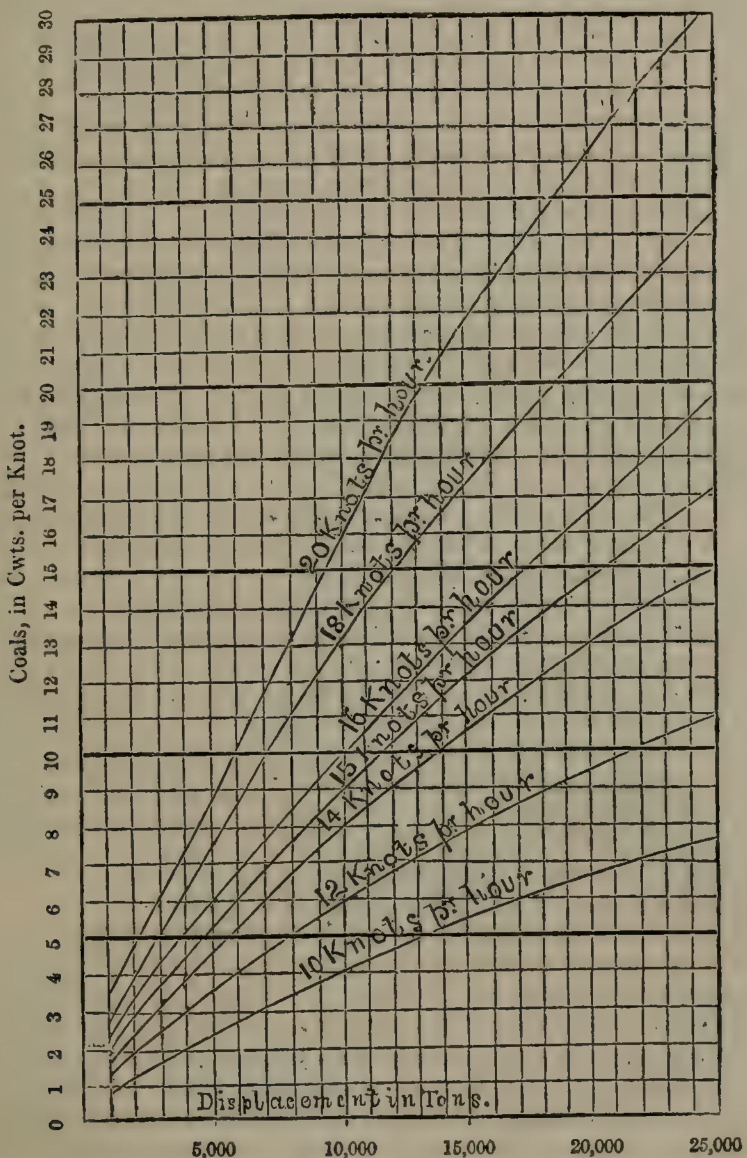
Calculated for the Speed of 10 knots per hour.

DISPLACEMENT.	Nominal H.P. taken at the unit 100,000 lbs. 1ft. per min.	Indicated H.P. taken at the unit 33,000 lbs. 1ft. per min.	COALS.		
			Per Day of 24 hours.	Per Hour.	Per Knot.
Tons.	H.P.	Ind H.P.	Tons.	Cwt.	Cwt.
250	52	159	4·26	3·55	·36
300	59	179	4·80	4·00	·40
350	66	199	5·33	4·44	·44
400	72	217	5·81	4·84	·48
450	78	235	6·30	5·25	·53
500	83	252	6·74	5·62	·56
600	94	285	7·63	6·36	·64
700	104	315	8·44	7·03	·70
800	114	345	9·24	7·70	·77
900	123	373	9·98	8·32	·83
1,000	132	400	10·70	8·92	·89
1,100	141	426	11·4	9·51	·95
1,200	149	452	12·1	10·1	1·01
1,300	157	476	12·7	10·6	1·06
1,400	165	501	13·4	11·2	1·12
1,500	173	524	14·0	11·7	1·17
1,600	181	547	14·6	12·2	1·22
1,700	188	570	15·4	12·8	1·28
1,800	195	592	15·8	13·2	1·32
1,900	203	614	16·4	13·7	1·37
2,000	210	635	17·0	14·2	1·42
2,250	227	687	18·4	15·3	1·53
2,500	243	737	19·7	16·4	1·64
2,750	259	785	21·0	17·5	1·75
3,000	275	832	22·3	18·6	1·86
3,250	290	878	23·5	19·6	1·96
3,500	304	922	24·7	20·6	2·06
3,750	318	965	25·8	21·5	2·15
4,000	333	1008	27·0	22·5	2·25
4,250	347	1050	28·1	23·4	2·34
4,500	360	1090	29·2	24·3	2·43
4,750	373	1133	30·2	25·2	2·52
5,000	386	1170	31·3	26·1	2·61
5,500	411	1246	33·4	27·8	2·78
6,000	436	1321	35·4	29·5	2·95
6,530	460	1393	37·3	31·1	3·11
7,000	483	1464	39·2	32·7	3·27
7,500	506	1533	41·0	34·2	3·42
8,000	528	1600	42·8	35·7	3·57
8,500	550	1666	44·6	37·2	3.72
9,000	571	1731	46·3	38·6	3·86
9,500	592	1794	48·0	40·0	4·80
10,000	613	1857	49·7	41·4	4·14
11,000	653	1978	52·9	44·1	4·41
12,000	692	2096	56·2	46·8	4·68
13,000	730	2211	59·2	49·3	4·93
14,000	767	2324	62·3	51·9	5·19
15,000	803	2433	65·2	54·3	5·43
20,000	973	2498	79·0	65·8	6·58
25,000	1129	3420	91·6	76·3	7·63

TABLE D.—Showing the Mutual Relations of Displacement, Power, and Coals consumed per Day, per Hour, and per Knot, for the respective Speeds of 10, 15, 20, and 25 Knots per Hour:—the Coefficient of Dynamic Performance deduced from the Formula $\frac{V^3 D^{\frac{2}{3}}}{\text{Ind. h. p.}}$ being assumed to be 250, and the Consumption of Coals at the rate of $2\frac{1}{2}$ lbs. per indicated horse-power per hour.

Displacement in Tons, at 35 cubic feet of Sea Water per Ton.	10 Knots.				15 Knots.				20 Knots.				25 Knots.			
	Ind. H. P.	Coals.			Ind. H. P.	Coals.			Ind. H. P.	Coals.			Ind. H. P.	Coals.		
		Per Day.	Pr Hour.	Pr Knot.		Per Day.	Pr Hour.	Pr Knot.		Per Day.	Pr Hour.	Pr Knot.		Per Da .	Pr Hour.	Pr Knot.
		Tons.	Cwt.	Cwt.		Tons.	Cwt.	Cwt.		Tons.	Cwt.	Cwt.		Tons.	Cwt.	Cwt.
1,000	400	10·7	8·92	·89	1350	36·1	30·1	2·0	3200	85·7	71·4	3·57	6250	167	139	5·56
1,200	452	12·1	10·1	1·01	1524	40·8	34·0	2·27	3614	96·8	80·7	4·03	7058	188	157	6·28
1,400	501	13·4	11·2	1·12	1689	45·2	37·7	2·51	4005	107	89·4	4·47	7822	210	175	7·00
1,600	547	14·6	12·2	1·22	1847	49·4	41·2	2·75	4377	117	97·7	4·88	8550	229	191	7·64
1,800	592	15·8	13·2	1·32	1998	53·5	44·6	2·98	4735	126	105	5·25	9248	247	206	8·24
2,000	635	17·0	14·2	1·42	2143	57·4	47·8	3·19	5080	136	113	5·65	9921	265	221	8·84
2,250	687	18·4	15·3	1·53	2318	61·8	51·5	3·43	5495	146	122	6·10	10,731	286	239	9·56
2,500	737	19·7	16·4	1·64	2487	66·6	55·5	3·70	5895	158	132	6·60	11,629	308	257	10·3
2,750	785	22·0	17·5	1·75	2650	70·9	59·1	3·94	6281	168	140	7·00	12,268	328	273	10·9
3,000	832	21·3	18·6	1·86	2808	75·2	62·7	4·18	6656	178	148	7·40	13,000	348	290	11·6
3,250	878	23·5	19·6	1·96	2962	79·3	66·1	4·40	7021	188	157	7·85	13,715	367	306	12·2
3,500	922	24·7	20·6	2·06	3112	83·3	69·4	4·63	7377	197	164	8·20	14,408	385	321	12·8
3,750	965	25·8	21·5	2·15	3259	87·2	72·7	4·85	7724	206	172	8·69	15,086	404	337	13·5
4,000	1008	27·0	22·5	2·25	3402	91·1	75·9	5·06	8064	216	180	9·00	15,749	421	351	14·0
4,250	1050	28·1	23·4	2·34	3542	94·9	79·1	5·27	8396	224	187	9·35	16,392	439	366	14·6
4,500	1090	29·2	24·3	2·43	3680	98·5	82·1	5·47	8722	233	194	9·70	17,036	456	380	15·2
4,750	1130	30·2	25·2	2·52	3815	102	85·1	5·67	9042	240	202	10·1	17,661	473	394	15·8
5,000	1170	31·3	26·1	2·61	3947	106	88.1	5·87	9357	251	209	10·4	18,215	488	407	16·3
6,000	1321	35·4	29·5	2·95	4458	120	100	6·67	10,566	283	236	11·8	20,637	553	461	18·4
7,000	1464	39·2	32·7	3·27	4940	132	110	7·33	11,710	313	261	13·0	22,870	612	510	20·4
8,000	1600	42·8	35·7	3·57	5400	145	121	8·01	12,800	342	285	14·2	25,000	670	558	22·3
9,000	1731	46·3	38·6	3·86	5841	156	130	8·67	13,846	371	309	15·4	27,042	724	603	24·1
10,000	1857	49·7	41·4	4·14	6266	167	139	9·27	14,853	398	332	16·6	29,010	778	648	25·5
12,000	2096	56·2	46·8	4·68	7076	190	158	10·5	16,772	449	374	18·7	36,760	877	731	29·2
14,000	2324	62·3	51·9	5·19	7842	210	175	11·7	18,588	498	415	20·7	46,305	972	810	32·4
16,000	2540	68·0	56·7	5·67	8572	229	191	12·7	20,320	544	453	22·6	39,684	1063	886	35·4
18,000	2748	73·6	61·3	6·13	9272	248	207	13·8	21,980	589	491	24·5	42,294	1150	958	38·3
20,000	2948	79·0	65·8	6·58	9948	266	222	14·8	23,580	631	526	26·3	46,048	1233	1028	41·1
22,000	3140	84·0	70·0	7·00	10,600	283	236	15·7	25,124	673	561	28·0	49,072	1314	1095	43·8
25,000	3420	91·6	76·3	7·63	11,542	310	258	17·2	27,359	733	611	30·5	53,436	1432	1193	47·7

DIAGRAM E, showing approximately the Nautical Mileage Consumption of Fuel, for vessels from 1000 tons displacement, up to 25,000 tons, the Coefficients of Dynamic Performance deduced from the Formula $\frac{V^3 D^{\frac{2}{3}}}{\text{Ind. h. p.}}$ being assumed to be 250, and the Consumption of Coals being assumed to be at the rate of $2\frac{1}{2}$ lbs. per Ind. h. p. per hour.



With reference to the foregoing Table C, showing the mutual relations of displacement, power, and the consumption of coals *per day*, *per hour*, *and per knot*, for vessels of a gradation of sizes, from 250 tons displacement up to 25,000 tons, the coefficient of dynamic performance, deduced from the formula $\frac{V^3 D^{\frac{2}{3}}}{\text{Ind. h. p.}}$ being assumed to be 250, and the consumption of coals being assumed to be at the rate of $2\frac{1}{2}$ lbs. per indicated h. p. per hour, on these data, the coefficient of dynamic economy with reference to coals deduced from the formula $\frac{V^3 D^{\frac{2}{3}}}{w}$ (w being the consumption of coals per hour expressed in cwts.) becomes 11210.

It will be observed that in Table C the tabulated sizes of ships, as determined by their respective load displacements, increase progressively from 250 tons displacement up to 25,000 tons, showing under assumed conditions, which, however, are justified by now realized advancement in ship and engine construction, the mutual relations of displacement and coals calculated for the speed of 10 knots per hour as most convenient for a standard of reference. The intended practical use of this Table C is to facilitate mercantile investigation into the dynamic merits of steam-ships as locomotive implements of burden by comparing their actual consumption of fuel with the calculated consumption of the ship of corresponding size and speed as recorded in this tabulated standard of comparison, whence the constructive merit of ships, as respects their *working economy of fuel, on which the cost of freight so much depends,* may be relatively ascertained. For example, a certain ship of 800 tons mean displacement attains the speed of 8·8 knots per hour, with a consumption of coals certainly not exceeding 4·3 cwt. per hour, or ·49 cwt. per nautical mile or knot; which (as the consumption of coals *per knot* varies *cæteris paribus* as the square of the speed) is equivalent to ·63 cwt. per knot at the speed of 10 knots per hour. Now by referring to Table C, we find that on the assumed data therein referred to, the standard ship of 800 tons displacement, steaming at 10 knots per hour, would consume ·77 cwt. of coal per knot. Hence, therefore, it appears that the ship referred to in this instance is *superior* to the tabulated standard in the proportion of ·77 to ·63, that is, in the proportion of 122 to 100, the superiority with reference to the consumption of coals per knot being 22 per cent.

Again, a certain ship of 3500 tons mean sea displacement makes a voyage at the average speed of 12·88 knots per hour, consuming 83 cwt. of coal per hour, or 6·44 cwt. per knot, which, by the law of dynamics above quoted, is equivalent to 3·88 cwt. per knot at the speed of 10 knots per hour; but by referring to the Table of comparison C, we find that the standard ship of 3500 tons displacement, steaming at 10 knots per hour, would consume only 2·06 cwt. of coal per knot. Hence, therefore, it appears that the ship referred to in this instance is *inferior* to the tabulated standard ship in the proportion of 2·06 to 3·88, that is, in the proportion of 53 to 100, the inferiority with reference to the consumption of coals being 47 per cent.

Thus, by reference to this tabulated standard of comparison (C), we have the means of readily deducing the exact per-centage by which ships, as respects the dynamic duty performed with reference to the consumption of coals, differ from each other. I need not dwell on the importance of this consideration as affecting the commercial value of ships for sale or charter.

With reference to Table D, showing the mutual relations of displacement, power, and coals consumed per day, per hour, and per knot for the respective speeds of 10, 15, 20, and 25 knots per hour, the object of this Table is to show the extent to which the required engine-power, and the nautical mileage consumption of coals are dependent on the rate of speed, thereby facilitating the adaptation of ships as respects their size and power to the service that may be required of them.

For example, by referring to Table D, we observe that a ship of 5000 tons displacement, steaming at 10 knots per hour, requires 1170 indicated h. p., and consumes 2·61 cwt. of coal per knot; but to steam 15 knots per hour, the same vessel would require 3947 ind. h. p., and the consumption of coals would be 5·87 cwt. per knot; hence it appears that to increase the speed from 10 to 15 knots per hour, the power requires to be increased upwards of three times, and the consumption of coals per knot is more than doubled.

Again, let it be supposed that the weight of the hull of a ship of 5000 tons displacement fitted for sea amounts to 40 per cent. of the displacement, or 2000 tons, and suppose the weight of the engines and boilers to be one ton for each 10 indicated h. p., the vessel requiring, as shown by Table D, 1170, indicated h. p. to attain the speed of 10 knots per hour, with a consumption of coals at the rate of 2·61 cwt. per knot; then on these data, the engines, to attain the speed of 10 knots per hour, would weigh 117 tons, and the weight of coals for a passage of, say 12,000 nautical miles, would be $12{,}000 \times 261 = 31{,}320$ cwt., or 1566 tons weight, making together for hull, engines and coals $2000 + 117 + 1566 = 3683$, and consequently the displacement available for cargo would be $5000 - 3683 = 1317$ tons weight. But if it be purposed that the steaming speed shall be at the rate of 15 knots per hour, the required power, as appears by Table D, will be 3947 ind. h. p., consequently the weight of the engines will be 395 tons, and the maximum displacement available for coals will be $5000 - 2395 = 2605$ tons weight, or 52,100 cwt., which, at the tabulated rate of consumption, 5·87 cwt. per knot, would be sufficient only for a passage of 8876 nautical miles, and this to the utter exclusion of all goods cargo, showing that the ship is inadequate for steaming 12,000 nautical miles at the required speed of 15 knots per hour, though the same ship, if duly fitted with engine-power for steaming at 10 knots per hour, would perform the whole passage of 12,000 nautical miles without re-coaling at any intermediate station, and carry 1317 tons of remunerating goods cargo.

These few examples will, it is hoped, sufficiently illustrate the application and use of Tables C and D in facilitating mercantile inquiry into the capabilities of steam-ships with reference to the all-important question of consumption of coals; but in order still further to facilitate calculations on this subject, the diagram E has been prepared, whence, simply by inspection, the consumption of coals per knot, at any rate of speed, may be approximately ascertained for vessels of improved modern construction up to 25,000 tons, the data on which this diagram has been calculated being the same as that on which Tables C and D are based.

The use and application of this Diagram E is evident; it brings the Tables under ocular review, and generalizes their application. It is given as an example of a system that admits of being more fully and elaborately developed for the purposes of mercantile tabular reference, as is now being done for publication.

Having thus explained the use and application of Tables C and D and the Diagram E, it will be perceived that the task which I have undertaken on this occasion is to show palpably by comparison with these tabular statements, *based on data within the limits of already realized results*, taken as a standard, what is the relative character of steam-ships as respects their locomotive or dynamic capabilities, with reference to the economic performance of mercantile transportservice, so far as dependent on the consumption of fuel; thus affording an exposition whereby parties interested in steam-shipping, either as owners or directors, or agents, or as the charterers of shipping for government or for private service, though unacquainted with the details of marine engineering as a science, may be enabled to arrive at some definite appreciation of the capabilities that may be expected of steamers; that is, the weight of cargo they will carry, and the length of passage capable of being performed at any definite speed; for, as before observed, the dead weight of cargo that a ship will carry is equal to the tons' weight of water displaced between the light and load water-lines of the ship, less the weight of coals and stores required for the voyage, and which for long voyages commonly amount to four times the weight of cargo chargeable as freight, and it constitutes the limitation of distance which the ship is able to run under steam at a given speed. This inquiry is therefore essential to a due appreciation of the economic consequences which are involved in progressive variations of steam-ship speed, especially as respects the high rates of speed, which are occasionally professed, but which are seldom realized, simply because there has been no recognized exposition, whereby such pretensions may be judged of with reference to the required consumption of fuel. In short, regarding this matter as a public cause, affecting as it does the pecuniary interest of the public to the extent of millions sterling per annum, my object is to promulgate, through the medium of the notoriety which every inquiry obtains upon its being brought before the "British Association for the Advancement of Science," a Mercantile Steam-ship Expositor, by reference to which as a standard of comparison the good or bad qualities of steam-shipping may be determined; and this surely is a public cause, for by the operation of the scrutiny which such a system of comparative exposition may be expected to inaugurate and popularize, steamers will soon become *marketable, with reference, in great measure, to their capabilities for economic transport service*, at the *speed* that may be required; under the influence of this scrutiny all bad types of form and vicious adaptation of mechanical system will be eradicated; incompetency in steam-ship management will become gradually eliminated, and the mercantile transport service of the country being then performed exclusively by good, well-appointed, and well-managed ships, would be performed at a *minimum* of cost to the shipping interests, and consequently to the *best advantage* for the interests of the public. Hitherto the dynamic character of steam-ships has been a mechanical problem enveloped in undefined and even delusive terms of shipping and engineering art; consequently its determination has not been based on any recognized principles of calculation. Hence the dynamical character of shipping has been a mystery—a matter of mere assertion on the one hand, and of credulity on the other. But mystery being unveiled, commercial vision will be opened, and competition, in shipping as in any other well-understood and open field of public enterprise, will ensure the mercantile transport service of the country being performed to the best advantage, and it will gradually establish and preserve the just equilibrium of freight charges as between the carriers and consumers of all sea-borne productions.

Report on the present state of Celestial Photography in England.

By Warren de la Rue, *Ph.D., F.R.S., Sec. R.A.S., &c.*

In bringing before the Association the present Report it will be only necessary, after referring briefly to the labours of others, to confine myself to an account of my personal experience; for, although other observers have occasionally made experiments in Celestial Photography, there has not been any systematic pursuit of this branch of Astronomy in England, except in my Observatory, and under my immediate superintendence in the Kew Observatory.

Part 1.

Historical Outline.

The late Professor Bond of Cambridge, in conjunction with Messrs. Whipple and Black of Boston in the United States, was the first to make a photographic picture of any celestial body. By placing a daguerreotype plate in the focus of the great refractor of the Harvard Observatory, of 15 inches aperture, he obtained a daguerreotype of our satellite. This was, I believe, about the year 1850, for I remember seeing one of these pictures in the Exhibition of 1851, and some were exhibited at the meeting of the Royal Astronomical Society in May 1851. The experiments were discontinued after a time in consequence of irregularities in the going of the clock-work driver, and were not resumed again till 1857, when new clock machinery was attached to the telescope*.

At the latter end of 1852, I made some successful positive lunar photographs in from ten to thirty seconds on a collodion film, by means of an equatorially mounted reflecting telescope of 13 inches aperture, and 10 feet focal length, made in my workshop, the optical portion with my own hands; and I believe I was the first to use the then recently discovered collodion in celestial photography†. In taking these early photographs, I was assisted by my friend Mr. Thornthwaite, who was familiar with the employment of that new medium‡. At that period, I had not applied any mechanical driving motion to the telescope, so that I was constrained to contrive some other means of following the moon's apparent motion; this was accomplished by hand; in the first instance, by keeping a lunar crater always on the wire of the finder by means of the ordinary hand-gear of the telescope, but afterwards by means of a sliding frame fixed in the eye-piece holder, the motion of the slide being adjustable to suit the apparent motion of our satellite; the pictorial image of the moon could be seen through the collodion film, and could be rendered immoveable in relation to the collodion plate, by causing one of the craters to remain always in apparent contact with a broad wire placed in the focus of a compound microscope, affixed at the back of the little camera box, which held the plate. Although these photographs were taken under the disadvantage referred to, namely, the want of an automatic driving motion, excellent results were nevertheless obtained, which proved how perfectly the hand may be made to obey the eye. I could not take photographs of the moon in this way alone, but required always the aid of an experienced coadjutor, willing to lose the greater portion of a night's rest, often to be disappointed by failures resulting from the state of the weather, and numberless impediments sufficient to damp the ardour of the most enthusiastic. For some months Mr. Thornthwaite was so kind as to continue his valuable aid, and several good positive pictures were obtained; but the difficulties we had to encounter were so great that it was at last resolved to discontinue the experiments until such time as a driving motion could be applied to the telescope. This was done early in 1857§, since which period I have unremittingly followed up the subject of celestial photography whenever my occupations and the state of the atmosphere have permitted me to

* Astronomische Nachrichten, No. 1105, p. 1.

† These pictures were exhibited in the early part of 1853 at the Royal Astronomical Society.

‡ Mr. Archer applied the solution of gun cotton (collodion) to photography in 1851, and suggested pyrogallic acid for developing the latent image.

§ Monthly Notices of the Roy. Ast. Soc. vol. xviii. p. 16.

do so. With what result, the Association will have an opportunity of judging by the examples exhibited*.

Professor Phillips, aided by Mr. Bates, obtained some lunar photographs in July 1853, and communicated the results of his experience in a valuable paper at the Hull meeting of the Association†. Mr Hartnup of Liverpool, aided by Mr. J. A. Forrest, Mr. McInnes, Mr. Crooke, and other photographers, took some good pictures of the moon in 1854‡; Father Secchi, at Rome, and more recently Mr. Fry, in Mr. Howell's observatory at Brighton, and Mr. Huggins, near London, have also produced lunar pictures: these experiments were in all cases made with refracting telescopes, corrected for the visual ray. Professor Bond, in April 1857, applied the process with promise of a fruitful future, in measuring the distance and angle of position of double stars§, and also in the determination of their magnitudes; just previous to his decease, this new application of the art appears to have engaged his attention more than lunar photography. He succeeded in obtaining pictures of fixed stars down to the 6–7th magnitude.

The Photographic Picture compared with the Optical Image.

It will render what I shall hereafter have to say more easily understood if I commence by bringing under notice what happens in applying photography to sidereal astronomy. The optical image of a fixed star, it will be remembered, is not a mathematical but an optical point, which, in consequence of the properties of light, is seen with the telescope as a very minute disc, surrounded by rings, which become fainter and wider apart as they enlarge, these rings being always more or less broken up, according to the state of the atmosphere. The photographic image must, therefore, be of a certain size, but it is after all a mere speck, difficult to find among other specks which are seen in the most perfect collodion film, when it is viewed with a magnifying power.

For example, let it be supposed that a telescope of sufficient aperture is turned upon α Lyræ; a star conveniently situated from its great meridional altitude for photography, and moreover sufficiently brilliant to give a nearly instantaneous picture: if the telescope be steadily supported at rest, the star will, in consequence of the earth's rotation, course along the field of the telescope, in a line parallel to the earth's equator, and, as it produces an instantaneous picture, the image obtained is a streak, representing the path of the star. We might be led to expect, *a priori*, that this line, for a short distance, would appear straight; but, so far from this being the case, it is broken up and distorted, and consists of a great number of undulating points, crowded in some places, and scattered in others. This distortion arises from the disturbances in our atmosphere which cause the star to flicker.

In the foregoing remarks, the telescope was supposed to be at rest; now

* The photographs exhibited at the Aberdeen Meeting were the following:—Two original negatives which would bear considerable magnifying power; two positive enlarged copies of other negatives, eight inches in diameter, which would bear still further enlargement with a lens of low power; twelve enlarged positives of the Moon in different phases, 3½ inches in diameter, among which were three, showing the progress of the lunar eclipse on February 27, 1858; enlarged positive copies of Jupiter, exhibiting his belts and satellites; lastly, a photograph of Saturn and the Moon taken together at the recent occultation of that planet just after the planet had emerged from the moon's bright limb (May 8, 1859). The last-named photograph was produced in 15 seconds;—a remarkably rapid result for so faint an object as Saturn. The planet on this occasion was seen to be of about the same brilliancy as the Mare Crisium situated near the moon's western limb, with which the planet could be readily compared, from its proximity to that lunar district.

† Report of Brit. Assoc. 1853, Trans. Sect. A, p. 14.

‡ Report of Brit. Assoc. 1854, Trans. Sect. B, p. 66.

§ Astronomische Nachrichten, No. 1105.

let it be assumed that the telescope is mounted on an axis parallel with the earth's axis, and provided with a driving apparatus, capable of carrying the telescope round in the direction of the star's apparent path so equably, that, if viewed with a micrometer eye-piece, the image of the star would remain always in contact with one of the wires of the eye-piece. The photographic picture of a star, obtained by a telescope under these conditions after some seconds' exposure, is not one single clear disc or point, but a conglomeration of points, extending over a greater or less area, according as the atmosphere has during the interval produced more or less flickering.

If a mere speck, like a fixed star, acquires comparatively large dimensions on a sensitized plate in consequence of atmospheric disturbances, every optical point in an image of other celestial objects must, from the same cause, occupy a space of greater dimensions than it would if no disturbing influences existed. When the telescope is employed optically, the mind can make out the proper figure of the object, although its image dances before the eye several times in a second, and is able to select for remembrance only the states of most perfect definition; on the other hand, a photographic plate registers all the disturbances. The photographic picture will consequently never be so perfect as the optical image with the same telescope, until we can produce photographs of celestial objects instantaneously: we are still a long way from this desirable end.

Relative Advantages of Reflecting and Refracting Telescopes for Photography.

With refracting telescopes, the photographic focus of a point of light occupies a larger area than with reflectors; this is especially the case with Astronomical Telescopes, because they are corrected so as to produce the best optical image, and the outstanding chemical rays are dispersed around the luminous focus*. The reflecting telescope has, therefore, considerable advantage over the refracting telescope for celestial photography, on account of all rays coming to focus in the same plane; hence, the focus having been adjusted for the luminous image, it is correct for the chemical image, and has not to be disturbed, as with a refractor. In the telescope employed by Professor Phillips, of $6\frac{1}{4}$ inches aperture and 11 feet focal length, the actinic focus was found to be 0·75 inch beyond the visual focus; and in the Liverpool Equatorial of $12\frac{1}{2}$ feet focal length the actinic focus was 0·8 inch beyond the visual focus. With my telescope the focusing is critically effected with the aid of a magnifier, the image being received on a piece of ground glass placed temporarily in the actual slide destined to contain the sensitized plate; a second piece of ground glass fixed in a frame is put into the camera just previous to each operation, for the purpose of placing the telescope in position; but the focusing is always effected in the manner described, for the goodness of the picture depends greatly on the accuracy of this adjustment. I attribute much of my success to the employment of a reflector, while my fellow-labourers in the same field have used refractors.

Actual Process employed at the Cranford Observatory.

With the view of facilitating the labours of others desirous of entering the field of photography, I will now describe, with all necessary minuteness, the process finally adopted after many trials and failures; I would remark at the same time that it is quite impossible to give such directions as will enable another operator to ensure perfect results, as this can only be attained by perseverance, long practice, and a strong determination to overcome obstacle after obstacle as it arises,—therefore, no one need hope for

* Refracting telescopes can be specially corrected for the chemical focus in the same way as Camera lenses.

even moderate success if he dabbles in celestial photography in a desultory manner, as with an amusement to be taken up and laid aside.

In order to prosecute celestial photography successfully, there must be, in close contiguity with the telescope, a Photographic Room, abundantly supplied with both common and rain water. The water-taps should project over a sink, so as to reach about a foot from the wall. The rain water is conveniently kept in and filtered by an ordinary stone-ware filter. The photographic room may be lighted generally by means of an ordinary Argand reading lamp, over the shade of which hangs a lantern-like curtain made of two thicknesses of deep-yellow calico; but the plate, during the development of the picture, must be illuminated locally by a night-light before which a yellow screen is placed. The photographic room should be furnished with a stove, burning wood or charcoal, which will keep alight for a long time, in order that its temperature may never fall much below 50° F. during the winter.

In my earlier experiments, the positive process was invariably employed on account of its greater rapidity; but so many details, visible by transmitted light in a positive, are lost when it is afterwards viewed by reflected light, that endeavours were made to render the negative process equally rapid. After many trials, I succeeded in this; and I now never have recourse to the positive process, except for some special object.

Glass used.—It is of course necessary to have the plate somewhat larger than the object to be taken; the size used when the telescope is employed as a Newtonian is $2\frac{5}{8}$ inches by $3\frac{1}{8}$ inches. When the pictures are taken by the direct method, the plates are circular, and $2\frac{3}{4}$ inches in diameter. The outside diameter of the slide to contain the circular plate is $3\frac{1}{4}$ inches, the exact size of the cell of the diagonal mirror, so that no more light is stopped out by the plate-holder than by the small mirror.

The glass used is the "extra white patent plate," and I have it selected as free from specks and bubbles as possible, but nevertheless I have frequently to reject about one-third of those discs which are supplied to me.

Mode of Cleaning the Plate.—The glass is cleaned in the ordinary way by means of tripoli powder, mixed up with three parts of spirit of wine and one of liquid ammonia, to the consistence of cream. For drying the plates I am provided with *two** cloths, which, in the first instance, have been carefully washed with soda (avoiding the use of soap), and repeatedly rinsed in water. Each time after being used, these cloths are thoroughly dried, but they need not be washed for months together. For the final wiping of the plate a piece of wash-leather is employed, also carefully dried before being used.

A piece of grit-stone, such as is used by mowers to sharpen scythes, must be at hand, for the purpose of grinding the edges of the glass plate and making scratches on the margin of the two surfaces, in order to cause the more perfect adherence of the collodion,

The plate to be cleaned is placed on a sheet of cartridge paper, and rubbed thoroughly, first on one side, then on the other, with a piece of *new* cotton-wool moistened with the tripoli mixture, above described. It is then washed in a stream of water, the fingers being used, if necessary, to aid in removing the adhering tripoli. Holding the plate while still wet, and without touching the surface, one edge after the other is rubbed on the grit-stone; the glass imbeds itself in the friable stone, and thus the borders of the two surfaces get scratched, and the edge is ground at the same time. After the four edges have been so ground, or, if the plate be circular, the whole periphery has been rubbed, the hands and plate are well washed, to remove all grit, and the plate placed edgewise for a few seconds on a marble slab. With dry

* It is disadvantageous to employ more cloths than are absolutely necessary.

hands, I take up the plate by the edge, being now very careful not to touch the surface with the hand, and wipe it, first with one cloth, then thoroughly dry with the second, and lastly, rub both surfaces at the same time with the dry wash-leather. I afterwards breathe on each side of the plate, to ascertain whether it is clean, wipe off the condensed moisture and place the plate in a grooved box, with the best surface turned to face a marked end of the box, so as to know on which side to pour the collodion. Proceeding in the above-described manner, I have never any failure attributable to a dirty plate, and can feel certain of obtaining four or five good pictures of the moon out of about seven plates generally used. I am usually, however, provided with one or two dozen cleaned plates, for it is desirable to have a sufficient reserve, and experience has proved that plates so cleaned may be used even after a week, if the box containing them be kept in a dry room.

The Bath.—It is of the utmost importance that the nitrate of silver bath should be in the most sensitive condition; the rapidity of the process appears to depend in a great measure on its not being in the slightest degree acid, but as nearly neutral as possible. It is almost needless to add that, for such a refined application of photography as that under consideration, the solution should be kept in glass in preference to gutta percha. The vessel must be carefully covered, to exclude dust, and, from time to time, the solution should be filtered through pure filtering paper (Swedish paper). The nitrate of silver used in the preparation of the bath is invariably fused in my own laboratory, in quantities never exceeding a drachm at one time, the requisite heat being gradually applied, and care being taken not to raise the temperature higher than is necessary to effect the fusion.

The solution I employ is the ordinary one of thirty grains of nitrate of silver to the ounce of water, with a quarter of a grain of iodide of potassium. In the preparation of a bath, after the mixing of the nitrate of silver, dissolved in a small portion of the water, with the solution of iodide of potassium, it is customary to add the remaining chief bulk of water, which causes an immediate precipitation of iodide of silver, and then to filter the liquid after the lapse of half an hour. It is, however, advisable to agitate the solution from time to time, during several hours before it is filtered; for unless this be done, the bath does not become thoroughly saturated with iodide of silver, and has a tendency for some time to dissolve a portion of the iodide of silver which first forms in collodion immersed in it.

I avoid adding alcohol or acetic acid to the bath, for these substances impair its sensitiveness. As, after use for a certain time, the bath becomes charged with more or less alcohol and ether, and their products of oxidation, its properties become changed, and a picture cannot be taken with it with sufficient rapidity; when I find this to occur, I discard the bath and make a fresh one. The bath, in its most sensitive state, usually exhibits a very feeble alkaline reaction with reddened litmus paper, and if it be found to have a tendency to fog, it is corrected in this way:—A single drop of pure nitric acid is taken on the point of a glass rod, and mixed with a drachm of distilled water; with this diluted acid (1 to 60) I moisten the point of the glass rod and stir it about well in the bath, which contains about fourteen fluid ounces of solution, and make a trial. If it still fogs, the acidification is repeated; and thus, after several trials, the fault is corrected. It is better to proceed in this manner than to rely on litmus papers as a test for neutrality; the object being to retain the bath in as sensitive a state as possible, the test by light is the only one to be ultimately depended on.

Moist hydrated oxide of silver may be used to bring back a bath, which has become acid by use, to a neutral state, and by the subsequent careful addition of dilute nitric acid it may be made to work; but all additions of acetate of soda, carbonate of soda, or acetic acid, are quite inefficacious for correcting a bath that does not work satisfactorily. In order to obtain the extreme point of sensitiveness, the best plan on the whole is to make a new bath; the silver being, as is well known, easily recoverable from its solutions and in part, by evaporation and crystallization, as nitrate.

Collodion.—The condition of the collodion is also an all-important point, and it appears to be very capricious in its properties. It is preferable not to make the collodion oneself, but to use that prepared by makers of repute; I usually employ Thomas's or Hardwich's collodion, both of which I have found to be very uniform in quality.

It is desirable to sensitize frequently new batches of collodion, and to determine by experiment from time to time the gradual development and decline of their sensitiveness.

Collodion should not be sensitized until after it has stood for, at least, a week after it has been purchased, and it must then be carefully poured into the mixing vessel without disturbing the sediment which always is present. It must be agitated occasionally for some hours after mixing with the sensitizer, before it is set aside to rest and deposit the new sediment which forms. After standing for a week, it should be carefully decanted for use, to the extent of three-fourths, into a perfectly clean glass vessel.

The glass mixing vessels should invariably, previous to use a second time, be washed out, first with a mixture of equal parts of ether and alcohol, and then with water and pieces of blotting-paper, well shaken up, so as to reduce the paper to pulp; and finally, rinsed out with distilled water, and suspended in a warm place, mouth downwards, to drain and dry thoroughly.

Iodide of cadmium appears, on the whole, to be the best sensitizer for collodion to be used in celestial photography: collodion, prepared with this salt, is not very active when first mixed; hence it differs from collodion prepared with iodide of potassium and iodide of ammonium in this respect, but it gradually acquires a degree of sensitiveness unsurpassed, if equalled, by collodion rendered active with the latter salts, used either alone or mixed with other salts. Collodion, mixed with iodide of potassium, acquires, it is true, great sensitiveness soon after it is prepared, but in a few days it loses in this respect, is moreover continually changing, and is seldom available in celestial photography after standing a month or six weeks; whereas cadmium collodion will retain its qualities for several months. As fresh mixed collodion is certain to produce both white and dark specks in the photograph, as large or larger than the details visible in the picture with a magnifier, it will be seen that a collodion which can be kept for a long time to deposit, without losing in sensitiveness, must be the most valuable; moreover, in collodion mixed with the alkaline iodides there is always an evolution of free iodine which soon impairs the sensitiveness of the nitrate of silver bath by rendering it acid; and for these reasons I generally give the preference to cadmium collodion.

Sometimes collodion exhibits a reticulated structure after the photograph has dried, which materially militates against the beauty of the picture, and prevents its being highly magnified; it occasionally happens that this defect cannot be cured, in which case the collodion should be rejected. I have generally found, however, that this "craping" may be obviated if the collodion be diluted, more or less, with a mixture of two parts of ether and one part of alcohol when it is being sensitized, care being taken to add as much of the solution of iodide in relation to the diluting liquids as would have to be added to an equal volume of collodion.

After using collodion for several evenings, it is well to allow it to stand for some days, and to decant about three-fourths into a fresh vessel.

Before pouring the collodion on to the glass plate, the usual precaution of cleaning away with the fingers any dried collodion from the lip of the containing vessel must be attended to; moreover, each time, just in the act of pouring, a few drops should be allowed to fall to waste on the floor; by attention to these remarks, much vexation will be avoided.

Exposure of the Plate in the Telescope.—On taking the plate from the nitrate of silver bath, it is desirable to drain it well before it is put into the slide, first on the edge of the bath, then on white blotting-paper, shifting its position two or three times, but always keeping the same point downwards. It must be carried to the telescope as quickly as possible, and the picture developed immediately after it has been removed from it.

The sensitized plate rests on angles of pure silver, let into the square plate-holder, or in the circular plate-holder within a ring of pure silver, the face resting on three prominent places. I have found that contact with wood is liable to produce stains which occasionally extend across the plate during the development. The circular plate-holder is entirely of metal, and I would recommend metal holders in preference to those of wood for celestial photography, because they are not liable to warp and become set from damp when left in the observatory. The plate-holder should be wiped with a clean cloth after each operation, and the hands also washed each time before a fresh plate is taken, on which it is intended to pour collodion.

In order to subject the sensitized plate to the action of light when the telescope is used as a Newtonian, I remove a very light cover, previously placed over the mouth of the telescope, and replace it when I wish to discontinue the action; this cover is made of black merino, stretched on a whalebone hoop and is provided with a handle of bamboo. In the direct method, I turn up or down, through an arc of 90°, a little hinged trap, interposed between the great mirror and the sensitive plate. This motion is given by means of a lever fixed on a light axis, supported by the arm which holds the small camera; the axis extending beyond the edge of the telescope tube, and carrying a milled head by which it is turned.

Regulation of the Time of Exposure.—A journeyman-clock, beating seconds distinctly, should be near the telescope, in order that the operator may be enabled to regulate the time of exposure, which requires great nicety with such sensitive chemicals as must be employed.

The time occupied in taking lunar pictures varies considerably; it depends on the sensitiveness of the chemicals, on the temperature, on the altitude of the moon and her phase. An almost imperceptible mist in the atmosphere will sometimes double the time of exposure, but, curiously enough, a bright fleecy cloud passing over the moon scarcely stops any of the actinic rays. I have recently produced an instantaneous picture of the full moon, and usually get strong pictures of the moon in that phase in from one to five seconds. The moon as a crescent, under like circumstances, would require about 20 to 30 seconds, in order to obtain a picture of all the parts visible towards the dark limb.

Development of the Picture.—Of all the developing mixtures tried, I give the preference to the aceto-pyrogallic acid solution, which is generally used in the ordinary proportions; namely, pyrogallic acid, three grains; glacial acetic acid, one fluid drachm; distilled water, three fluid ounces; but, in cold weather, I sometimes reduce the quantity of acetic acid to one half, to render the solution more active. The developing fluid retains its properties for a week or more after mixing. It is desirable to pour out the requisite quantity of fluid in a small vessel, and to place it in readiness, before the plate is removed from the bath and put into the slide, so as to prevent any delay after the plate has been exposed in the telescope. This precaution obviates the staining which arises sometimes by partial drying of the film.

The addition of nitrate of silver to aid in bringing out the picture must be avoided; pictures thus intensified will not bear any magnifying power, and are comparatively worthless. Hence it will be seen how all-important it is to have the bath and collodion in their most sensitive condition. The negative should not be developed too strongly, as such pictures never copy so well as those moderately but distinctly brought out. Such small photographic pictures as those of Jupiter and Saturn present many obstacles to their development, on account of the difficulty of discerning them during the operation; for the focal image of Jupiter in my telescope, even when the planet is in opposition, is only about $\frac{1}{37}$th of an inch in diameter.

After the development of the picture to the desired point, the further development is arrested by pouring a quantity of water on the plate, and a vessel containing water should be at hand for this purpose.

Fixing the Picture.—By preference I use hyposulphite of soda for fixing; after fixing, the plate is washed under the tap of a cistern of water for a short time, and then examined with a lens. If worth retaining, the epoch of the picture, and other particulars are recorded at the back with a writing diamond. The plate is then washed again, front and back, in a stream of water, and placed face upwards on a tripod stand, duly levelled; rain-water* is poured on the collodion, and from time to time this is poured off and fresh poured on, in the meantime other photographs are proceeded with. After half an hour or more, the plate is thoroughly washed in a stream of rain-water, and placed edgewise on blotting-paper against the wall, to drain and dry.

Varnishing.—The next morning, the negatives are warmed before a fire, and varnished with Sœhnée's varnish†, which is the only description I have found to stand. I am careful to filter the varnish before using; otherwise specks might be transferred to the photograph. It is very desirable to varnish the plates as soon as they are dry, for, if left unvarnished for any length of time, they can never be varnished evenly.

Desiderata in the Machinery for driving the Telescope.

As in the production of celestial photographs some seconds of exposure are requisite, it is essential to have a clock-work driver to the telescope, which works uniformly and smoothly, and which is also capable, when lunar pictures are to be taken, of ready adjustment to the ever-varying lunar time. Lunar time, it will be recollected, differs from sidereal time, in consequence of the moon's variable motion in her orbit in a direction opposite to that of the apparent diurnal movement of the stars. A driving clock, if adjusted to follow a star, must be retarded therefore, more or less, in order to follow the moon. In my own telescope, this is at present effected by altering the length of the conical pendulum or friction governor, thus altering the time of its rotation (or double beat), and this plan, or some modification of it, is universal. My experience, however, has pointed out several inconveniences in thus changing the speed of the governor or pendulum, and it is my intention to make such alterations in the construction of the clock as will enable me

* In preparing the bath and developing solutions, distilled water must be employed, but filtered rain-water answers very well for washing the photographs.

† Sold by Messrs. Gaudin, 26 Skinner Street, London.

to alter the going of the telescope without changing the rate of the pendulum. This I propose to do by substituting an arrangement, similar to that known in mechanism as the disc and plate, for the wheel-work now connecting the machinery of the clock with the pendulum; the disc and plate being capable of producing a variable motion, according as the disc is nearer to or farther from the centre of the plate. The pendulum will, by the proposed plan, be driven by frictional contact, and, having employed this system in other machinery, I feel persuaded that its application to the clock-driver will not be attended with difficulty or inconvenience.

The moon, besides her motion in right ascension, has also a motion in declination, which is greatest when she is situated in one of the nodes formed by the intersection of the plane of the moon's orbit and the plane of the earth's equator, and is least when situated 90° from these nodes, where it vanishes. As this motion is at times very considerable, it is evident that, with a telescope made only to rotate round the polar axis, the best results will be obtained, all other circumstances being alike, when the motion in declination is at zero. Assuming that, on the average, 15 seconds are necessary for taking a lunar photograph, the moon may have shifted upwards of 4″ of arc in declination during that period; and evidently many details would be lost and the others considerably distorted. In order to ensure the most perfect results under all circumstances, it is desirable to give a movement to the declination axis of the telescope simultaneously with the movement of the polar axis. Hitherto, so far as I am aware, no means have been devised to effect this, but the requisite adjustable motion might be transmitted by means of the disc and plate above described, from the driving-clock, although its pendulum moves with a uniform velocity.

Lord Rosse's Method.—In my original method of taking the pictures by means of the sliding eye-piece before spoken of, both motions in right ascension and declination were provided for by adjusting the slide in the diagonal parallel with the moon's apparent path. Lord Rosse, at a subsequent period, applied a clock-movement to such a slide, and made some experiments in celestial photography*; but, the telescope being required for other special purposes, it appears that they were not long continued. This motion of the plate-holder does not meet all the exigencies of the case, but if one of his magnificent reflectors were arranged to move bodily along a guide adjustable in the direction of the moon's path, by means of some such mechanism as I have alluded to, I believe that lunar pictures might be produced of exquisite beauty, because defects in the collodion film and the glass plate would be of less consequence than with telescopes of shorter focal length, the image being larger in the ratio of focal length; for example, even with the three-foot instrument it would be 3 inches in diameter.

Degree of Perfection hitherto attained in Lunar Photography.

In my own telescope, the picture of the moon is only about $1\frac{1}{10}$in. in diameter; it might be suggested that the image could be enlarged by means of a combination of lenses before reaching the sensitized plate, but this would have the effect of prolonging the time of exposure, and moreover introduce the disadvantages of the refracting telescope, and the result would not be so good, for even if the moon's motion in declination were followed automatically, still the outstanding atmospheric disturbances before alluded to would remain†. Indeed, if the aperture of the telescope could be considerably increased in relation to its focal length, much finer pictures would be procured, because the time of exposure would be shortened. In practice it

* Monthly Notices of the Roy. Ast. Soc. vol. xiv. p. 199.
† Ibid. vol. xviii. p. 17.

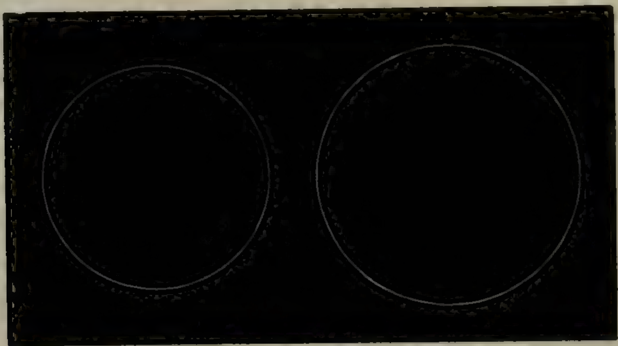
has been found preferable not to magnify the focal image, but to take enlarged positive copies on glass direct from the original negative, by means of an enlarging camera, and in this way the impressions, 8 inches in diameter, exhibited at the Meeting were produced.

In making positive copies, some of the more minute details are, unfortunately, always lost, for no means exist by which enlarged positive copies can be produced showing all the treasures of the original negative; a perfect enlarging lens being still a desideratum*. As an instance may be cited the streak in the lunar disc, which Mr. James Nasmyth has called "the railroad," indicated in Beer and Mädler's map as a straight line to the east of the crater Thebit between latitude 19° and 23° south, and between longitude 7° and 9° east. In the photograph it is shown to be a crack in the lunar crust with an irregular outline, and the eastern edge is perceived to be depressed below the western, which forms a perpendicular cliff. This, although sharply defined in the negative, is frequently lost in positive copies. For the examination and micrometrical measurement of the minuter details which celestial photography is capable of furnishing, recourse must still be had to the original negative.

Notwithstanding the disturbances which arise from the atmosphere, minute irregularities in the driving-clock, and the want of means for following the moon's motion in declination, I have obtained pictures of the moon that bear examination with the three-inch object-glass of a compound microscope magnifying about $16\frac{3}{4}$ times, and which show with good definition details occupying a space less than two seconds in each dimension. Two seconds are equal to about $\frac{1}{860}$th of an inch on the collodion plate in the focus of my telescope, and in the finest photographs, details occupying less than $\frac{1}{1000}$th of an inch are discernible with the three-inch object-glass; hence much valuable work has already been accomplished. A second on the lunar surface at the moon's mean distance being about one mile (1·149 mile), it will be evident that selenological disturbances, extending over two or three miles, would not escape detection, if such occur, provided photographs continue to be taken for a sufficiently long period.

Lunar Phenomena recorded by Photography.

Full Moon.—Variations of apparent Diameter.—By the delineation of our satellite, photography brings out palpably several phenomena which, although



well known, are not always present to the mind; for example, about every 29 days it is stated that there is a full moon, but we see by the photographic picture that there never is a full moon visible to us, except just before or just

* May 1860.—As these sheets are passing through the press, the author has been informed by Mr. Dallmeyer (son-in-law of the late Mr. Andrew Ross) that he has brought his investigations on this subject to a successful termination, and that he has just produced enlarging and diminishing lenses which copy without any sensible distortion or dispersion.

after a lunar eclipse, or at all events except when the sun, earth, and moon are very nearly in the same plane; at all other periods of the full moon we are unfavourably situated for seeing the whole of the illuminated hemisphere. Moreover, the different apparent diameter of the moon at various times, dependent on her distance from the earth, comes out in unmistakeable prominence in a collection of photographs; for the pictures taken with my reflector vary in diameter from one inch to one inch and nearly two-tenths (1·0053 inch to 1·1718 inch, being at the moon's mean distance 1·0137 inch).

When positive enlarged copies are made, it is easy to obtain all the pictures of exactly the same dimensions by the adjustment of the distance of the negative to be copied from the lens of the camera; and my enlarging camera is furnished with screws to facilitate the adjustment of the distance of the object to be copied, and also that of the focusing screen.

Libration.—We are familiar with the terms "diurnal libration," and libration in "latitude" and "longitude," yet it is difficult to realize the great amount of disturbance in the aspect of the moon's disc, and the direction of the displacement from the mean position which these several causes produce unless aided by photography, when we see them palpably before us.

The diurnal or parallactic libration never exceeds $1^\circ\ 1'{\cdot}5$; the direction of the displacement in the markings on the lunar disc which it produces is variable, and is dependent partly on the position of the observer.

The poles of the moon at the epoch of Mean Libration are situated in the periphery, and the equator and all parallels of latitude are straight lines; the circles of longitude being more or less open ellipses, varying from a straight line in the centre to a circle at the periphery. This occurs when our satellite is either in perigee or apogee (when the libration in longitude is at a minimum), and she is also situated in one of the nodes of her orbit (when the libration in latitude vanishes): the nodes, apsides, and moon would, under these circumstances, be in the same line.

Libration in Longitude merely causes a change of place in the various circles of longitude, which still continue to be more or less open ellipses; the parallels of latitude straight lines.

Those lunar craters, however, situated on the central meridian at the epoch of mean libration would be on a straight line, but, at the periods of maximum eastern or western libration, they would be seen arranged on a semi-ellipse, whose conjugate diameter is 0·1377, the moon's diameter being unity. Therefore a point at the centre of the moon's equator becomes shifted by the sum of the librations to the east and to the west to the extent of more than $\frac{1}{8}$th of the moon's diameter, namely 0·0688 to the east, and the same quantity to the west of the mean position. On account of perspective, the effect of libration in longitude is much less apparent on the eastern and western peripheral meridians, which shift towards the centre by a quantity equal only to $\frac{1}{229}$th of the moon's diameter (0·0048).

The equator and its parallels, which at the period of mean Libration in Latitude were straight lines, become more or less open ellipses under other circumstances; the ratio between the conjugate and transverse axes of all the parallels being constant for a given inclination of the lunar axis. At a maximum libration in latitude the equator becomes an ellipse, whose conjugate axis is 0·1181; the transverse axis being equal to the diameter of the moon considered as unity: so that a point in the centre of the equator is shifted 0·059 of the diameter to the north or to the south by a maximum northern or southern libration, and will move by the sum of these librations to an apparent extent of $\frac{1}{9}$th of the diameter of the lunar disc. The apparent motion of the north and south poles towards the centre is on account of perspective only $\frac{1}{286}$th of the diameter (0·0035).

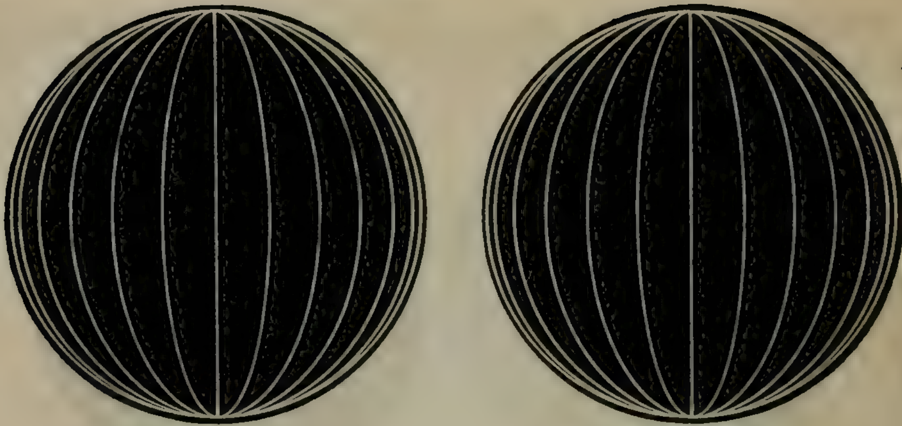
Libration in latitude also causes a change in the ellipses which delineate the meridians, causing an inclination of their axes to the line joining the poles, and also a change in the ratios of their transverse to their conjugate axes. For example, the meridian distant 7° 55′ from the centre (this being the position of central meridian at a maximum libration in longitude) would have its transverse axis inclined 0° 56′·3 to the pole, the conjugate axis being no longer 0·1377 but 0·1368 of the transverse. The peripheral meridians would no longer be semi-circles, but semi-ellipses, whose conjugate diameter is equal to 0·9965, and whose transverse diameter is inclined 90° to the pole.

Stereoscopic Pictures of the Moon.—Taking advantage of the libration, we may, by combining two views taken at sufficiently distant periods, produce stereoscopic pictures which present to the eyes the moon as a sphere. It has been remarked by the Astronomer Royal, that such a result is an experimental proof of the rotundity of our satellite. A dispute has been going on between photographers as to the proper angle for taking terrestrial stereoscopic pictures, and I infer that one side of the disputants would consider my arrangement of moon-pictures to produce stereographs unnatural, because under no circumstances could the moon itself be so seen by human eyes; but, to use Sir John Herschel's words, the view is such as would be seen by a giant with eyes thousands of miles apart: after all, the stereoscope affords such a view as we should get if we possessed a perfect model of the moon and placed it at a suitable distance from the eyes, and we may be well satisfied to possess such means of extending our knowledge respecting the moon, by thus availing ourselves of the giant eyes of science.

It does not follow as a matter of course that any two pictures of the moon taken under different conditions of libration will make a true stereoscopic picture; so far from this being the case, a most distorted image would result, unless attention be paid first to the selection of the lunar pictures, and then to their position on the stereoscopic slide. It is possible to determine beforehand, by calculation, the epochs at which the two photographs must be taken in order to produce a stereoscopic picture; but so many circumstances stand in the way of celestial photography, that the better course is to take the lunar photographs on every favourable occasion, and afterwards to group such pictures as are known to be suitable.

A little consideration of what has been before stated will show that two lunar pictures, differing only by libration, either in longitude or in latitude, will give a true stereoscopic effect, provided the angular shifting is sufficiently great.

On the other hand, if the two pictures differ both by libration in latitude and in longitude, they will give a true stereoscopic picture provided they satisfy the following condition. Suppose a point in the centre of the equator, when the moon is in a mean state of libration, has become shifted at the epoch of picture A in any given direction, and let an imaginary line pass through that point and the centre of the lunar disc, if at the epoch of picture B the point lies anywhere in the direction of that line, then a true stereograph will be obtained, provided the two pictures be suitably placed in the stereoscope.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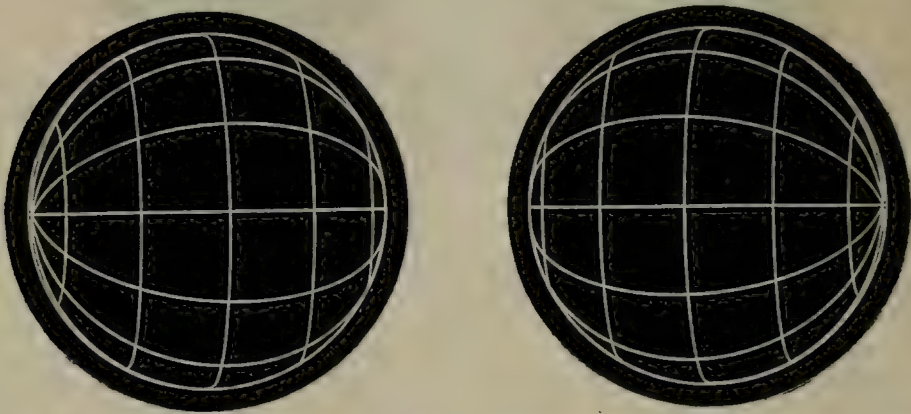
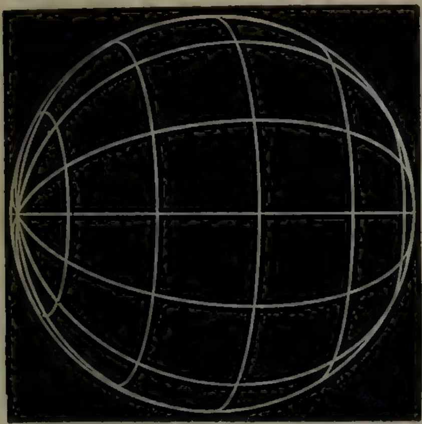


Assuming the space between the eyes to be $2\frac{3}{4}$ inches, and the nearest distance for distinct vision to be about 10 inches, we find 15° 48′ as the maximum stereoscopic angle. The possible shifting of the position of an object on the lunar disc from east to west by libration in longitude may amount to 15° 50′, which is almost identical with the assumed maximum stereoscopic angle, and the displacement from north to south, by libration in latitude, never exceeds 13° 34′, which falls within that angle. By the joint

effect of a maximum libration in longitude and latitude, a point on the lunar surface may, however, be shifted nearly 21°, which is greater than that under which an object could be viewed by the eyes.

* The centres of these diagrams should be $2\frac{3}{4}$ inches distant to give a stereoscopic picture.

An exaggerated protuberance of the central portion of the moon might result from the combination of two pictures obtained, at two epochs of maxima, in directions diagonally opposite, and the moon would appear somewhat egg-shaped. We may convince ourselves that this would be the case, by viewing, in the stereoscope, two suitably drawn orthographic projections of the lines of longitude and latitude of the sphere, especially if we purposely exaggerate the angle still more; for example, if we make the libration in latitude the double of what it is in reality.



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At the meeting at Leeds last year, there were exhibited some of my stereoscopic lunar pictures 8 inches in diameter, and an apparatus constructed expressly for viewing them. The instrument is of similar construction to Wheatstone's reflecting stereoscope; but, the objects being transparent, the usual arrangements and adjustments are considerably modified. Prisms with slight curvatures worked on their surfaces are employed, instead of mirrors, for combining the pictures which can be revolved and moved horizontally and vertically in order to place them in the true position. The effect of rotundity is perfect over the whole surface; and parts which appear like plane surfaces in a single photograph, in the stereoscope, present the most remarkable undulations and irregularities.

Light and Shade in the Photograph as compared with that of the Optical Image.—Portions of the moon, equally bright optically, are by no means equally bright chemically; hence the light and shade in the photograph do not correspond in all cases with the light and shade in the optical picture. Photography thus frequently renders details visible which escape observation optically, and it therefore holds out a promise of a fertile future in selenological researches; for instance, strata of different composition evidently reflect the chemical rays to a greater or less extent according to their nature, and may be thus distinguished †. The lunar surface very near the dark limb is copied photographically with great difficulty, and it sometimes requires an exposure five or six times as long, to bring out completely those portions illuminated by a very oblique ray, as others, apparently not brighter, but more favourably illuminated:—the high ground in the Southern hemisphere of the moon is more easily copied than the low ground, usually called seas, which abound in the Northern hemisphere: from these circumstances I ventured, in another place‡, to suggest that the moon may have an atmo-

* These diagrams should be $2\frac{3}{4}$ inches from centre to centre to give a stereoscopic picture.

† Professor Phillips has also noticed this difference between the visual and actinic brightness of portions of the lunar surface. Report of the Brit. Ass., 1853, Section A. p. 16.

‡ Monthly Notices Roy. Ast. Soc. vol. xviii. pp. 18 and 111.

sphere of great density, but of very small extent, and that the so-called seas might be covered with vegetation. This idea respecting a lunar atmosphere has, I am inclined to believe, received some confirmation from a recent observation of Father Secchi's, that the lunar surface polarizes light most in the great lowlands and in the bottoms of the craters, and not appreciably on the summits of the mountains.

Radiating Lines in the Moon's Disc.—The mountain peak in the centre of Tycho, about one mile in height, is very distinct in the photographs, and under favourable circumstances the details in the interior of the crater are well shown. The external slopes under all illuminations are darker in the photograph than the internal walls and the bottom of the crater. Tycho would appear to have been the focus of a wonderful disturbing force which broke up the moon's crust nearly over the whole visible surface, for radiating lines converge in that conspicuous volcano, like so many circles of longitude, and cannot fail to attract attention. Several theories have been suggested to account for these radiating lines; by studying a series of photographs taken under different conditions of illumination one becomes convinced that they are due to furrows in the lunar surface*. They are in some cases overlaid by craters which must have been formed at a subsequent period; and in other cases the furrow has dislocated the crater, which must therefore have previously existed.

One very remarkable Furrow fully fifty miles broad, extending from Tycho over 45° of latitude in a north-easterly direction, is the deepest on the lunar surface. The eastern ridge of this furrow skirts Mount Heinsius, and the western ridge extends to Balliald and Euclides, where the furrow becomes very shallow, but is traceable as far as Kepler.

Another conspicuous furrow runs from Tycho in a north-westerly direction nearly up to the northern limb of the moon, and extends over 100° of latitude, passing through Menelaus and Bessel in the Mare Serenitatis through a crater (marked E in Beer and Mädler's map) at the head of a promontory running into the Lacus Somniorum, when it is crossed by another furrow extending tangentially to the Apennines. The intersection of these streaks resembles the letter X, and indicates another focus of disturbance near the crater E in north latitude 35° and west longitude 24°. The main furrow from Tycho continues on through the crater Plana, leaving Burg untouched on the east, and terminates to the south of Strabo in north latitude 60° and west longitude 45°.

A furrow best seen about the full moon or a little after, extends from Tycho, though not quite continuously, through the Mare Nectares, traversing the crater A on the west of the crater Theophilus; sweeping in a curve eastward, it leaves Tarantius on the west, and crosses the bright crater Proclus, forming an eastern tangent to Berzelius. Leaving Endymion to the south-east, it forms the southern boundary of the Mare Humboldtianum in north latitude 70° and west longitude 90°, having traversed 110 degrees of latitude.

A remarkable focus of dislocation exists in the Mare Fœcunditatis in latitude 16° south and longitude 50° west, which also, by the crossing of the lines of disturbance, looks like another letter X in the photograph.

The radiating lines of dislocation are so numerous that it would be impossible, within reasonable limits, to describe any but the principal ones; I should state, however, that they must not be confounded with the sinuous lines which radiate from Copernicus and other lunar craters, and which are markedly different in character and origin.

* Monthly Notices Roy. Ast. Soc. vol. xviii. p.111.

Value of Photography in the Production of Selenographical Charts.

Pictures of Copernicus may be cited as an example of the aid photography would afford in mapping the lunar surface: this becomes especially apparent when an original negative is examined with a compound microscope. The details brought out in and around this crater in a fine negative by a three-inch object-glass are quite overwhelming from their number and variety. Not only the elaborate network of sinuous radiating lines on the exterior of Copernicus, but also the terraces in the internal walls of that wonderful volcano, the double central cone, the curvature of the sole of the crater, and its polygonal form, all appear in vigorous outline.

Again, photographs of the Apennine ridge, under different illuminations, are among the most beautiful of the results of the application of the art to selenography; it renders conspicuously evident many details of tint and form in that extensive ridge, which would escape the most careful scrutiny of the visual picture unless attention was previously directed to them by the photograph. Unaided by photography, it would indeed be almost hopeless to attempt a correct representation of that wonderful chain of mountains, affected as its form is, on account of its vast extent, by libration, and also on account of the changes in the shadows occasioned by the varying direction of the illumination. Aided by my collection of pictures, I hope to be able to acquit myself in a creditable manner of the trust I have accepted, and to contribute that quota of the lunar surface allotted to me by the British Association.

If, at a future period, the entire lunar surface is to be again mapped down, photography must play an all-important part, for, as Messrs. Beer and Mädler remarked in their invaluable work on the moon, it is quite impossible to complete even a tolerably satisfactory representation of our satellite in those rare and short moments when the mean libration occurs. One is therefore obliged to observe the moon under many different conditions of libration, and to reduce each measurement and sketch to the mean before the mapping can be proceeded with; for not only the position, but also the shape of the objects is altered by libration even from one evening to another. On the other hand, with photography at command, we may obtain in a few seconds pictures of the moon at the epochs of mean libration, and accumulate as readily a great number of records at other times. The latter would furnish, after reduction to the mean, a vast number of normal positions with which the more minute details to be seen with the telescope might be combined.

By means of a microscope, with a camera-lucida prism fixed on the eye-piece, enlarged drawings are readily made of different dimensions by varying the magnifying power and the distance of the paper from the eye-piece; with a normal magnifying power of seventeen times linear, drawings of lunar craters can be conveniently made of the exact scale used by Beer and Mädler for the large edition of their maps, by simply placing the drawing paper at the proper distance. These drawings may then be rendered more complete from time to time by filling in the minuter details by actual observation, and in this way materials accumulated for a selenographical chart such as even the skill and perseverance of a Mädler could not hope to accomplish.

Photography of the Planets.

Occasionally I take photographs of the fixed stars, and among others have made pictures of the double star Castor, but, as a general rule, I leave the fixed stars under the able custody of the Harvard Observatory, Cambridge, U.S., and devote my attention chiefly to the moon, making, however, from time to time, photographs of the planets under the rare circumstance of a quiescent state of the atmosphere.

In photographing the planets, it is sometimes advantageous to take several pictures on the same plate; this can be conveniently done with my telescope, because the driving clock is connected with the telescope by means of a peculiar spring clutch formed of two face-ratchet-wheels. When one picture has been taken, the image is shut off, and the ratchet disconnected, so that the telescope remains at rest, the clock continuing to go. During the interval of rest, which interval is conveniently regulated by the passage of a certain number of teeth of the moving half of the clutch, the planet will have moved through a short distance in its diurnal arc; and when the clock has been again thrown into gear, the image will fall on another part of the plate. In this way, four or five images of a planet, for example Jupiter, may be obtained in a very short time. These images are arranged at equal distances along an arc of right ascension, and afford a ready means of determining the angle of position of the belts, &c., as was proposed by the late Professor Bond with respect to the angle of position of double stars.

Relation of Actinic Power to Luminosity.—I have alluded before to the difference in the optical and photographic picture of the moon; another very remarkable result of photography is the great difference which has been proved to exist in the relation of actinic power to luminosity of the various celestial objects. For example, the occultation of Jupiter by the moon, on November 8th, 1856, afforded an excellent opportunity for comparing the relative brightness of our satellite and that planet. On that occasion, Jupiter appeared of a pale greenish tinge, not brighter than the crater Plato, and, according to my estimate, of about one-third the general brilliancy of the moon; but the actinic power of Jupiter's light was subsequently found to be equal to fully four-sixths or five-sixths of that of the moon*.

Saturn required twelve times as long as Jupiter to produce a photograph of equal intensity on an occasion specially favourable for making the experiment; yet I obtained a picture of Saturn together with that of the moon in 15 seconds on May the 8th of the present year, just as the planet emerged from behind the moon's disc. The picture of the planet, although faint, is sufficiently distinct to bear enlarging.

With two pictures of the moon and a planet (or a bright fixed star) taken at a short interval at the period of an occultation, or near approach of a planet or star by the moon, we may obtain a stereoscopic picture which would make the moon (seen, of course, as a flat disc) appear nearer than the planet or star.

Stereoscopic Pictures of the larger Planets.—Photographs of the planet Jupiter, although far inferior hitherto to the optical image seen with an eye-piece, show the configuration of the belts sufficiently well to afford us the means of producing stereoscopic pictures; all that is necessary is to allow an interval to elapse between the taking of the two pictures, so as to profit by the rotation of that planet on its axis. In the space of 26 minutes the planet will have rotated through the 15° 48′ necessary to produce the greatest stereoscopic effect.

Mars would, in 69 minutes, have rotated through the same angle, and, as his markings are very distinct, we may hope to obtain stereoscopic views of that planet.

The markings on the other planets are too faint to hold out a promise of similar results. Although this is the case with respect to Saturn, the ap-

* Monthly Notices Roy. Ast. Soc. vol. xviii. p. 55.

parent opening and closing of his ring as he revolves round his orbit affords us the means of obtaining a stereoscopic picture. Thus photographic reductions of the two original drawings which I made in November 1852 and March 1856 placed in the stereoscope (in such a manner that the major axes of the rings are at right angles to the line joining the eyes) give a picture in which the planet appears as a spheroid encircled by his system of rings, although the difference of position of the two pictures amounts only to 7°. And there is no reason why we may not obtain a stereoscopic picture composed of photographs taken actually from the planet.

Loss of the Actinic Rays by Reflection.

Until very lately, my celestial photographs were obtained by placing the sensitized plate at the side of the tube, opposite to the diagonal reflector of the Newtonian telescope; hence the light, before it reached the plate, was twice reflected. As it requires a very firm support for the diagonal speculum, of even a 13-inch mirror, to prevent vibration, the arm carrying this mirror was firmly screwed to the side of the telescope-tube, and rendered immoveable; I could not therefore make experiments in taking the pictures direct, that is to say, with the light only once reflected, without some alteration to the diagonal holder. I have, however, within the last few months, contrived an apparatus which permits of the ready removal and replacement of the diagonal mirror without impairing its stability, and celestial pictures are now taken at will, either direct or reflected out at the side of the tube; moreover it requires but a minute to change the apparatus to produce either result. With these means, I am able to make experiments to determine the relative actinic intensity of the light after one or two reflections. The experiments are still in progress, and have been begun so recently, that it is scarcely advisable to hazard a conjecture as to the result; but I may say that I am disappointed as to the increased rapidity of the production of a celestial picture by the direct method over the twice-reflection method; and I am inclined to infer that Steinheil's result as to the loss by reflection from speculum metal of the luminous ray does not hold as regards the actinic ray.

In concluding the first part of this report, I would remark that to photograph the moon continuously is a laborious undertaking, and affords full occupation for one observer, who must not fail to pay unremitting attention to the condition of the various chemicals employed, so as to be always prepared for a fine night with such as will work. I would therefore strongly urge the claims of this new branch of astronomical science to a more extended cultivation than it has hitherto received, with the conviction that it will require the ardent co-operation of many astronomers to develope fully its rich resources.

PART II.—*Photoheliography at the Kew Observatory.*

The Photoheliograph erected at the suggestion of Sir John Herschel* at the Kew Observatory has already been described in the Reports of the Kew Committee, 1856–57† and 1858‡, and in the Report for the present year.

It will not, however, be out of place to give some account of the instrument as at present actually in use, for, whilst part of the apparatus originally

* Report Brit. Assoc. 1854, p. xxxiv. † Id. 1857, p. xxxiv. ‡ Id. 1858, p. xxxiv.

provided has been found unnecessary, it has been deemed desirable to make some additions to the instrument from time to time.

The object-glass of the photoheliograph, it will be remembered, is of $3\frac{4}{10}$ inches clear aperture and 50 inches focal length, but the whole aperture is never used; it is always diminished more or less, and generally to about 2 inches, by a stop placed in front of the object-glass. The focal image of the sun at the mean distance is 0·466 inch. The focal image is not, however, received directly on the sensitive plate, as in the case of taking lunar and planetary photographs, but is enlarged before it reaches it by means of a secondary combination of lenses (an ordinary Huyghenian eye-piece), which increases the picture to about 4 inches in diameter, thus magnifying the image about eight times linear, and diminishing the intensity of the light 64 times.

The object-glass (made by the late Mr. Ross) is specially corrected to ensure the coincidence of the visual and chemical foci; but, as might be anticipated, the rays, after passing through the secondary lens, are in some degree dispersed, and this coincidence of foci no longer exists. It required some considerable time to determine exactly the position of the actinic focus; ultimately it was proved, after numerous trials, that the best photographic definition is obtained when the sensitized plate is placed from $\frac{1}{10}$th to $\frac{1}{8}$th of an inch beyond the visual focus, and that this adjustment must be modified to a slight extent according as more or less of the aperture of the object-glass is employed.

Difficulties of Photoheliography.—Whilst in lunar and stellar photography many of the obstacles to be overcome arose from the deficiency of photographic power in the unenlarged focal images of those celestial objects, the difficulties which have stood in the way of producing good sun-pictures arose in a great degree from the incomparably greater brilliancy in the sun's image, even when its intensity was considerably lessened by stopping off a large portion of the object-glass, and magnifying the diameter of the image very greatly. In order to overcome these obstacles, recourse was had at an early period to the less sensitive media than wet collodion, such, for example, as are used in the albumen and the dry collodion processes. None of these attempts were, however, productive of sufficiently promising results to encourage the pursuit of the trials in this direction, and I may mention that I made simultaneous experiments in taking unenlarged pictures in the focus of my reflector, on dry collodion and albumen, with no better result. The surfaces in these processes are indeed very rarely sufficiently free from impurities for the delineation of such minute objects as solar spots, and the processes themselves present disadvantages which render them inapplicable to photoheliography.

After many unsuccessful trials a return was at last made to the collodion process. Former experience having shown that the shortest exposure possible with the means then at command produced only a solarized image, in which all trace of the sun-spots was obliterated, recourse was had to the interposition of yellow glass between the principal and secondary object-glasses, with the view of diminishing the actinic intensity of the sun's image; nevertheless only burnt-up pictures were produced.

Instantaneous Apparatus.—It will be evident, therefore, that, for the successful employment of a medium so sensitive as wet collodion, it was absolutely necessary to contrive some means for reducing the time of its exposure to the sun's influence to an extremely small fraction of a second. Any apparatus placed in front of the object-glass, it was conceived, would have the disadvantage of cutting off the aperture by successive non-symmetrical portions, and of producing an image less perfect than when the exposed portion of the object-glass remained always concentric and circular. On the other hand, it was seen that a slide with a rectangular opening, if caused to move across the tube in front of the sensitized plate, would in no way distort the picture, but would merely stop off a portion of it, and have the effect, as it moved along, of allowing each part of the sun's image to act in succession on different parts of the collodion, and there to record itself; but a rapidly moving object close to the collodion-plate is so liable to cause a disturbance of dust, and its consequent lodgement on the collodion-film, that the carrying out of the idea in this manner was given up.

The late much-lamented Director of the Observatory, Mr. Welsh, suggested the plan which was ultimately adopted with success; instead of placing the sliding apparatus close to the collodion-plate, he proposed that it should be made on a smaller scale and fixed as near the plane of the primary focus as possible. Mr. Beckley has skilfully carried out this suggestion; so that the apparatus answers its intended object most perfectly, and the production of a solar picture is now at least as easy as that of a lunar picture. The sliding plate is very light, and moves so freely, that it does not, while in motion, disturb the telescope in the slightest degree; it is drawn downwards by means of a spring of vulcanized caoutchouc, and as soon as it is released it shoots with great rapidity across the field. The sliding plate has two apertures, one circular, and sufficiently large to permit of the passing of all the rays; this is used for the purpose of focusing on the screen, and also in observing contacts of the sun's limb with the wires to be hereafter described. The second aperture is square, and is fitted with a sliding piece actuated by a screw, which projects beyond the telescope tube; by means of this screw the aperture may be completely closed or readily reduced to a slit of any required width, equal to or smaller than the side of the square opening, a divided scale being affixed to the screw for that purpose.

Previous to taking a picture the sliding plate is drawn up just so high that an unperforated part of it completely shuts off the sun's image; the plate is held in this position by means of a small thread attached to it at one end, and looped at the other, the loop being passed over a hook on the top of the tube. When the picture is about to be taken, the retaining thread is set on fire, and the rectangular aperture, as soon as the sliding plate becomes released, flashes across the axis of the secondary object-glass, thus allowing the different parts of the sun's image to pass through it in succession, and to depict themselves, after enlargement, successively on the collodion-plate. Although the time of exposure is so short as to be scarcely appreciable, yet it is necessary to regulate its duration; and it is therefore controlled by adjusting, 1st, the strength of the vulcanized caoutchouc spring; 2nd, the width of the aperture. In practice, the opening is usually varied between $\frac{1}{10}$th and $\frac{1}{20}$th of the diameter of the sun's focal image.

No driving Machinery needed, except at the period of a Total Eclipse.— It will be seen from the foregoing description that the clock-work driving apparatus, described at page xxxv. of the reports for 1857, can be of no service, because the photograph is taken in so small a fraction of time that no appreciable distortion of the sun's image would result in the interval by allowing the telescope to remain at rest. So rapid is the delineation of the sun's image, that fragments of the limb, optically detached by the "boil" of our atmosphere, are frequently depicted on the collodion, completely separated from the remainder of the sun's disc; more frequently still from the same cause the contour of the sun presents an undulating line.

Although the clock-work driver is unnecessary for the daily work of the photoheliograph, it may prove of great value on the rare occasions of a total solar eclipse. It is to be hoped that it will enable the contemplated expedition to Spain, in July of next year, to obtain a photographic record of the feeble light of the Corona and the Red Flames; but it is by no means certain that their light will be sufficiently intense for that object. Even a failure, however, will prove of some value, for it will show that the image of these phenomena, when enfeebled by an enlargement of eight times linear, possesses too little actinic power to imprint their outline on a collodion-plate in a given number of seconds; and thus data will be furnished for a future period.

It is desirable that other astronomers should endeavour to obtain photographs of these data by placing the sensitized plate directly in the focus of the telescope.

In taking photographs with the Kew Photoheliograph, the telescope, clamped in declination, is placed a little in advance of the sun, and then clamped in right ascension; the thread is set on fire as soon as the centre of the sun coincides with the axis of the instrument. In order that the operator may know when this is the case, a secondary camera or finder is fixed on the top of the pyramidal tube of the telescope*. This finder consists of an achromatic lens of long focus, which is so placed as to throw an image of the sun on to a plate of brass fixed vertically near the lower or broad end of the tube, and consequently in a convenient position for the operator to see both the image and the retaining thread which holds the slide. The brass plate has ruled on it several strong lines, two of which are just so far apart and so situated as to form tangents to the sun's limb when the image is exactly central; a lighted match, held in readiness, is at this precise moment applied to the thread, and the slide immediately flashes across the secondary object-glass.

Position Wires.—The position of the solar spots in respect to a normal point is determined by placing a system of wires in a certain known position in the telescope. Originally the wires were four in number, two being fixed at right angles to the other two, the distance between each pair being somewhat less than the semidiameter of the sun; so that when one wire of each pair was situated near the sun's centre the other cut off a small arc at the limb. The position of the wires was such that the one pair was parallel to a circle of declination.

Some inconvenience was occasionally experienced in consequence of one or other of the four wires obliterating a solar spot; hence an alteration is now being made in the apparatus for holding the wires. Instead of attaching them to a fixed diaphragm placed between the two lenses of the secondary object-glass, they will be fastened to a sliding diaphragm with two apertures; across one of the apertures only will be fixed the wires, so that a photograph may be taken either with or without them. No appreciable distortion in the photographic image of the wires can be detected.

The wires will be two in number; they will cross each other at an angle of 90°, and form an angle of 45° with a circle of declination. This system of wires is the same as that proposed by Mr. Carrington and used in his observations of solar spots. It is intended when the apparatus is complete to observe the contacts of the sun's limb with the wires as it passes them in succession each day before commencing a set of photographs, and also immediately after completing them. In order to observe these contacts, the image of the sun and wires will be received on the ground-glass focusing plate, and the times of the several transits noted by viewing the image of the sun and wires through the plate. One photograph will in all cases be taken with the wires, and two or three without the wires, in order to secure all the details possible, as well of the faculæ as of the spots.

Degree of perfection attained. Stereoscopic pictures of the Sun.—By over-

* Report Brit. Assoc. 1857, p. xxxv.

exposure of the collodion the faculæ first disappear, then the penumbræ round the spots, and lastly the spots themselves. In the photograph the difference in the intensity of the sun's limb and central portions is very marked, but an over-exposure prevents also this from being seen in the photograph. The solar spots and faculæ delineated by the Kew Photoheliograph bear examination with a lens of moderate power, and show details not visible to the unassisted eye. The faculæ and spots are sufficiently marked to make the sun appear globular when two views taken at a sufficient interval are grouped together in the stereoscope, as will be seen by the slides now before the Meeting. There is not the same difficulty in obtaining stereoscopic pairs of views of the sun as there is in the case of the moon, because any two views taken at an interval of about a day give a perfectly spherical figure in the stereoscope. When the principal spots are near either limb, two views taken at an interval of two days will combine, and even slight changes in the form of the spots do not prevent the perfect coalition of the two pictures.

Having already most fully described the methods pursued and the precautions to be taken to ensure good results in the case of photoselenography, it will be unnecessary for me here to enter into any details of the chemical part of the processes of photoheliography, for the methods are nearly the same in both cases. So far from seeking a surface less sensitive than ordinary collodion, it has been found advisable to use both the bath and collodion in a very sensitive condition, though it is not of course necessary to strain this sensitiveness to the utmost extent for solar photography, as in the case of lunar photography. The bath must, however, be always brought back to its best working state by means of oxide of silver, and subsequent addition of dilute nitric acid in case it has become acid by use. The collodion moreover is used in that condition which photographers would call very sensitive.

On the Orders of Fossil and Recent Reptilia, and their Distribution in Time. By Professor Owen.

[A communication ordered to be printed entire among the Reports.]

With the exception of geology, no collateral science has profited so largely from the study of organic remains as zoology. The catalogues of animal species have received immense accessions from the determination of the nature and affinities of those which have become extinct, and much deeper and clearer insight has been gained into the natural arrangement and subdivision of the classes of animals since Palæontology has expanded our survey of them. Of this the class *Reptilia*, or cold-blooded air-breathing vertebrates, affords a striking example.

In the latest edition of the 'Règne Animal' of Cuvier, 1829, as in the 'Elémens de Zoologie' of Milne-Edwards (1834–37), and in the more recent monograph on American *Testudinata* by Prof. Agassiz, 4to, 1857, the quadruple division of the class, proposed by Brongniart in 1802, is adhered to, viz. *Chelonia* (Tortoises, Turtles); *Sauria* (Crocodiles, Lizards); *Ophidia* (Serpents); *Batrachia* (Frogs, Newts); only the last group is made a distinct class by the distinguished Professor of the United States*. In my former Reports on Fossil Reptiles to the British Association, in 1839 and 1841, it was proposed to divide the class into eight orders, viz.—*Ena-*

* "After this separation of the Batrachians from the true Reptiles, we have only three orders left in the class Reptiles proper—the Ophidians, the Saurians, and the Chelonians." —*l. c.* p. 239.

liosauria, *Crocodilia*, *Dinosauria*, *Lacertilia*, *Pterosauria*, *Chelonia*, *Ophidia* and *Batrachia*, which orders were then severally characterized.

Subsequent researches have brought to light additional forms and structural modifications of cold-blooded air-breathing animals now extinct, which have suggested corresponding modifications of their distribution into ordinal groups. Another result of such deeper insight into the forms that have passed away has been the clearer recognition of the artificiality of the boundary between the classes *Pisces* and *Reptilia* of modern zoological systems.

The conformity of pattern in the arrangement of the bones of the outwardly well-ossified skull in certain fishes with well-developed lung-like air-bladders, e. g. *Polypterus*, *Lepidosteus*, *Sturio*, and in the extinct reptiles *Archegosaurus* and *Labyrinthodon*;—the persistence of the notochord (*chorda dorsalis*) in *Archegosaurus*, as in *Sturio*; the persistence of the notochord and branchial arches in *Archegosaurus* and *Lepidosiren*; the absence of occipital condyle or condyles in *Archegosaurus* as in *Lepidosiren*; the presence of teeth with the labyrinthic interblending of dental tissues in *Dendrodus*, *Lepidosteus*, and *Archegosaurus*, as in *Labyrinthodon*; the large median and lateral throat-plates in *Archegosaurus*, as in *Megalichthys*, and in the modern fishes *Arapaima* and *Lepidosteus*;—all these characters, as were explained and reasoned upon in my lectures at the Government School of Mines (March, 1858), pointed to one great natural group, remarkable for the extensive gradations of development linking and blending together piscind and reptilian characters within the limits of such group. The salamandroie (or so called 'sauroid') Ganoids, e. g. *Lepidosteus* and *Polypterus*, are the most ichthyoid, the Labyrinthodonts are the most sauroid, of this annectent group: the *Lepidosiren* and *Archegosaurus* are intermediate gradations, one having more of the piscine, the other more of the reptilian characters. *Archegosaurus* conducts the march of development from the fish proper to the labyrinthodont type; *Lepidosiren* conducts it to the perennibranchiate or modern batrachian type. Both forms expose the artificiality of the ordinary class-distinction between *Pisces* and *Reptilia*, and illustrate the naturality of the wider class of cold-blooded vertebrates, which I have called *Hæmatocrya* *.

Reptiles are defined as 'cold-blooded air-breathing vertebrates,' but the *Siren* and *Proteus* chiefly breathe by gills, as did, most probably, the *Archegosaurus*. The modern naked *Batrachia* annually mature, at once, a large number of small ova; the embryo is developed with but a small allantoid appendage, and is hatched and excluded with external gills. These are retained throughout life by a few species; the rest undergo a greater or less degree of metamorphosis. Other existing reptiles have comparatively few and large eggs, and the embryo is enclosed in a free amnios and is more or less enveloped by a large allantois; it undergoes no marked transformation after being hatched.

On this difference, the *Batrachia* have been, by some naturalists, separated as a distinct class from the *Reptilia*. But the number of ova simultaneously developed in the viviparous Land Salamanders is much less than in the Siren, and not more than in the Turtle; and, save in respect of the external gills which disappear before or soon after birth, the Salamander does not undergo a more marked transformation, after being hatched, than does the Turtle or Crocodile †. It depends, therefore, upon the value assigned to the different proportions of the allantois in the embryo of the salamander and lizard, whether they be pronounced to belong, or not, to distinct classes of animals.

* αἷμα, blood, κρύος, cold; the correlative group is the '*Hæmatotherma*.'

† The *Cæcilia* may probably depart still further from the type-batrachian mode of development, and approach more to the type-reptilian mode.

This embryonic or developmental character is unascertainable in the extinct *Archegosaurus* and *Labyrinthodon*. The signs of affinity of *Labyrinthodon* to *Ichthyosaurus*, and those structures which have led the ablest German palæontologists to pronounce the Labyrinthodonts to be true Saurians under the names of *Mastodonsaurus*, *Trematosaurus*, *Capitosaurus*, &c., may well support the conjecture that modifications more 'reptilian' than those in *Salamandra* did attend the development of the young Labyrinthodont.

Characters derived from the nature of the cutaneous coverings equally fail to determine the class-characters of *Batrachia* as contradistinguished from *Reptilia*. It is true that all existing *Batrachia* have a scaleless skin, or very minute scales (*Cæcilia*), but not all existing Reptiles have horny scales. The Crocodiles and certain Lizards show a development of dermal bones similar to that in certain placoid and ganoid fishes. This development characterizes the cutaneous system in the Labyrinthodont genus *Anisopus*; and in regard to the dermal ossifications of the cranium, the resemblance to the *Ganoidei* is closer in those ancient forms of *Reptilia* which exhibit in their endoskeleton unmistakeable signs of their affinity to fishes and batrachians.

In the survey which, with a view to communicate its results to the present Meeting of the British Association, I have made of all the known forms of cold-blooded air-breathing Vertebrates, recent and fossil, I have to acknowledge myself unable to define any adequate boundary for dividing them into two distinct classes of Batrachians and Reptiles; and I am as little able to point out a character dividing the air-breathing from the water-breathing *Hæmatocrya*—the Reptiles from the Fishes.

In the present Report, therefore, an arbitrary line has been drawn, in order to define its subject, between *Lepidosiren* and *Archegosaurus*, and the review of the ordinal groups of *Reptilia*, or air-breathing *Hæmatocrya*, will commence with that of which the *Archegosaurus* is the type.

Order I. Ganocephala.

The name of *Ganocephala*, for this group or order (γάνος, lustre; κεφαλή, head), has reference to the sculptured and externally polished or ganoid bony plates with which the entire head is defended. These plates include the 'post-orbital' and 'super-temporal' ones, which roof over the temporal fossæ. There are no occipital condyles. The teeth have converging inflected folds of cement at their basal half. The notochord is persistent, the vertebral arches and peripheral elements are ossified, the pleurapophyses are short and straight; there are both pectoral and pelvic limbs, which are natatory and very small; there are large median and lateral 'throat-plates': the scutes are small, narrow, subganoid. Some of the fossils show traces of branchial arches. The above combination of characters gives the value of an ordinal group in the cold-blooded Vertebrata.

The extinct animals which manifest it were first indicated by certain fossils discovered in the sphærosideritic clay-slate forming the upper member of the Bavarian coal-measures, and also in splitting spheroidal concretions from the coal-field of Saarsbrück near Treves; these fossils were originally referred to the class of Fishes (*Pygopterus Lucius*, Agassiz). But a specimen from the 'Brandschiefer' of Münster-Appel presented characters which were recognized by Dr. Gergens to be those of a Salamandroid Reptile*.

* Mainz, Oktober 1843.—"In dem Brandschiefer von *Münster-appel* in *Rhein-Baiern* habe ich in vorigen Jahre ∞ einen Salamander aufgefunden":—"Gehort dieser Schiefer der Kohlen-formation?—in desene falle wäre der Fund auch in anderen Hinsicht interessant." Leonhard und Bronn, Nue Jahrbuch für Mineralogie, &c., 1844, p. 49.

Dr. Gergens placed his supposed 'Salamander' in the hands of M. Hermann von Meyer for description, who communicated the result of his examination in a later number of the under-cited journal*.

In this notice the author states that the Salamander-affinities of the fossil in question, for which he proposes the name of *Apateon pedestris*, "are by no means demonstrated†..... Its head might be that of a fish, as well as of a lizard or of a batrachian..... There is no trace of bones or limbs." M. v. Meyer concludes by stating that, "in order to test the hypothesis of the *Apateon* being a fossil fish, he has sent to Agassiz a drawing with a description of it."

Three years later, better preserved and more instructive specimens of the problematical fossil were obtained by Professor von Dechen from the Bavarian coal-fields, and were submitted to the examination of Professor Goldfuss, of Bonn. The latter palæontologist published a 4to memoir on them, with good figures, referring them to a Saurian genus which he calls *Archegosaurus*, or 'primeval lizard,' deeming it to be a transitional type between the fish-like Batrachia and the Lizards and Crocodiles‡.

The estimable author, on the occasion of publishing the above memoir, transmitted to the Reporter excellent casts of the originals therein described and figured. These casts were presented to the Museum of the Royal College of Surgeons, London, and were described by me in the 'Catalogue of the Fossil Reptiles' in that Museum (4to, 1854). The conclusions which I then formed as to the position and affinities of the *Archegosaurus* in the Reptilian class are published in that Catalogue, and were communicated to and discussed at the Geological Society of London (see the 'Quarterly Journal of the Geological Society,' vol. iv. 1848).

One of the specimens appeared to present evidence of persistent branchial arches. The osseous structure of the skull, especially of the orbits, through the completed zygomatic arches, indicated an affinity to the Labyrinthodonts; but the vertebræ and numerous very short ribs, with the evidence of stunted swimming limbs, impressed the Reporter with the conviction of the near alliance of the *Archegosaurus* with the *Proteus* and other perennibranchiate reptiles.

This conclusion of the affinity of *Archegosaurus* to existing types of the Reptilian class is confirmed by the subsequently discovered specimens, described and figured by M. von Meyer in his 'Palæontographica' (Bd. vi. Heft 2. 1857), more especially by his discovery of the embryonal condition of the vertebral column§, *i. e.* of the persistence of the notochord, and the restriction of ossification to the arches and peripheral vertebral elements.

In this structure, the old carboniferous Reptile resembled the existing *Lepidosiren*, and thus affords further ground for regarding that remarkable existing animal as one which obliterates the line of demarcation between the Fishes and the Reptiles.

Coincident with this non-ossified state of the basis of the vertebral bodies of the trunk is the absence of the ossified occipital condyles, which condyles characterize the skull in better developed *Batrachia*. The fore part of the notochord has extended, as in *Lepidosiren*‖, into the basi-sphenoid region,

* Leonhard und Bronn, Neues Jahrbuch für Mineralogie, 1844, p. 336.

† "Ob das—*Apateon pedestris*—ein Salamander-artiges Geschöpf war, ist keineswegs ausgemacht."

‡ "'Archegosaurus,' Fossile Saurier aus dem Steinkohlengebirge die den Uebergang der Ichthyoden zu den Lacerten und Krokodilen bilden," 'Beitrage zur vorweltlichen Fauna des Steinkohlengebirges' (4to, 1847), p. 3.

§ 'Reptilien aus der Steinkohlen-Formation in Deutschland,' Sechster Band, p. 61.

‖ Linn. Trans., vol. xviii. p. 333, pl. 24, fig. 2.

and its capsule has connected it, by ligament, to the broad flat ossification of expansions of the same capsule, forming the basi-occipital and basi-spheoid plate.

The vertebræ of the trunk in the fully developed full-sized animal present the following stage of ossification. The neurapophyses coalesce at the top to form the arch, from the summit of which is developed a compressed, subquadrate, moderately high, spine; with the truncate, or slightly convex, summit expanded in the fore-and-aft direction, so as to touch the contiguous spines in the back; the spines are distinct in the tail. The sides of the base of the neural arch are thickened and extended outwards into 'diapophyses' having a convex articular surface for the attachment of the rib; the fore part is slightly produced at each angle into a zygapophysis looking upward and a little forward; the hinder part is much produced backwards, supporting two-thirds of the neural spine, and each angle is developed into a zygapophysis with a surface of opposite aspects to the anterior one. In the capsule of the notochord three bony plates are developed, one on the ventral surface, and one on each side, at or near the back part of the diapophysis. These bony plates may be termed 'cortical parts' of the centrum, in the same sense in which that term is applied to the element which is called 'body of the atlas' in Man and Mammalia, and 'sub-vertebral wedge-bone' at the fore part of the neck in Enaliosauria.

As such ventral or inferior cortical element co-exists with the separately ossified centrum in certain vertebræ of the *Ichthyosaurus*, thus affording ground for deeming them essentially distinct from a true centrum, I have applied the term 'hypapophysis' to such independent inferior ossifications in and from the notochordal capsule, and by that term may be signified the sub-notochordal plates in *Archegosaurus*, which co-exist with proper 'hæmapophyses' in the tail. In the trunk the hypapophyses are flat, subquadrate, oblong bodies, with the angles rounded off: in the tail they bend upwards by the extension of the ossification from the under- to the side-parts of the notochordal capsule, sometimes touching the lateral cortical plates. These serve to strengthen the notochord and support the intervertebral nerve in its outward passage.

The ribs are short, almost straight, expanded and flattened at the ends, round and slender at the middle. They are developed throughout the trunk and along part of the tail, coexisting there with the hæmal arches, as in the *Menopoma**.

The hæmal arches, which, at the beginning of the tail, are open at their base, become closed, in succeeding vertebræ, by extension of ossification inwards from each produced angle, converting the notch into a foramen. This forms a wide oval, the apex being produced into a long spine; but towards the end of the tail the spine becomes shortened, and the hæmal arch is reduced to a mere flattened ring. The size of the canal for the protection of the caudal blood-vessels indicates the powerful muscular actions of the long tail; as the produced spines, from both neural and hæmal arches, bespeak the provision made for muscular attachments, and the vertical development of the caudal swimming organ.

All these modifications of the vertebral column demonstrate the aquatic habits of the *Archegosaurus*; the limbs being, in like manner, modified as fins, but so small and feeble as to leave the main part of the function of swimming to be performed, as in fishes and Perennibranchiate Batrachia, by the tail.

The skull of the *Archegosaurus* appears to have retained much of its pri-

* Principal Forms of the Skeleton, 'Orr's Circle of the Sciences,' p. 187, fig. 11.

mary cartilage internally, and ossification to have been chiefly active at the surface, where, as in the combined dermo-neural ossifications of the skull in the sturgeons and salamandroid fishes, e. g. *Polypterus*, *Amia*, *Lepidosteus*, these ossifications have started from centres more numerous than those of the true vertebral system in the skull of Saurian reptiles.

The teeth are usually shed alternately; they consist of osteo-dentine, dentine, and cement. The first substance occupies the centre, the last covers the superficies of the tooth, but is introduced into its substance by many concentric folds extending along the basal half. These folds are indicated by fine longitudinal straight striæ along that half of the crown. The section of the tooth at that part gives the same structure which is shown by a like section of a tooth of the *Lepidosteus oxyurus**.

The same principle of dental composition is exemplified in the teeth of most of the ganoid fishes of the Carboniferous and Devonian systems, and is carried out to a great and beautiful degree of complication in the Old-red Dendrodonts.

The repetition of the same principle of dental structure in one of the earliest genera of *Reptilia*, associated with the defect of ossification of the endoskeleton and the excess of ossification in the exoskeleton of the head, decisively illustrate the true affinities and low position in the Reptilian class of the so-called *Archegosauri*.

For other details of the peculiar and interesting structure of the animals representing the earliest or oldest known order of Reptiles, the Reporter would refer to his article "Palæontology" in the 'Encyclopædia Britannica,' and to the works by Goldfuss and Von Meyer, above cited.

Order II. Labyrinthodontia.

This name, from λαβύρινθος, a labyrinth, and ὀδοὺς, a tooth, refers to the complex structure characterizing the teeth, in the several genera of the order; in which, also, the head is defended, as in the *Ganocephala*, by a continuous casque of externally sculptured and usually hard and polished osseous plates, including the supplementary 'postorbital' and 'supratemporal' bones, but leaving a 'foramen parietale†.' There are two occipital condyles. The vomer is divided and dentigerous. There are two external nostrils. The vertebral centra, as well as arches, are ossified, and are biconcave. The pleurapophyses of the trunk are long and bent. The teeth are rendered complex, at least at the basal part of the crown, by undulations and side-branches of the converging folds of cement; whence the name of the order.

The reptiles presenting the above characters have been divided, according to minor modifications exemplified by the form and proportions of the skull, by the relative position and size of the orbital, nasal, and temporal cavities, and by dermal characters, into several genera; as, e. g. *Mastodonsaurus*, *Anisopus*, *Trematosaurus*, *Metopias*, *Capitosaurus*, *Zygosaurus*, *Xestorrhytias*, &c.

The relation of these remarkable reptiles to the Saurian order has been advocated as being one of close and true affinity, chiefly on the character of the extent of ossification of the skull and of the outward sculpturing of the cranial bones. But the true nature of some of these bones appears to have been overlooked, and the gaze of research for analogous structures has been too exclusively upward. If directed downward from the *Labyrinthodontia* to the *Ganocephala*, and to certain ganoid fishes, it suggests other conclusions which I have developed in my article "Palæontology" above referred to.

* Wyman, 'American Journal of the Natural Sciences,' October, 1843.

† The corresponding vacuity is larger in some ganoid fishes.

There is nothing in the known structure of the so-named *Archegosaurus* or *Mastodonsaurus* that truly indicates a belonging to the Saurian or Crocodilian order of reptiles. The exterior ossifications of the skull and the canine-shaped labyrinthic teeth are both examples of the Salamandroid modification of the ganoid type of fishes.

The small proportion of the fore-limb of the *Mystriosaurus* in nowise illustrates this alleged saurian affinity, for, though it be as short as in *Archegosaurus*, it is as perfectly constructed as in the Crocodile; whereas the short fore limb of *Archegosaurus* is constructed after the simple type of that of the *Proteus* and *Siren*. But the futility of this argument of the sauroid affinities is made manifest by the proportions of the hind limb of *Archegosaurus*; it is as stunted as the fore limb: in the Labyrinthodonts it presented larger proportions, which, however, may be illustrated as naturally by these proportions in the limbs of certain *Batrachia* as by the proportions of the limbs of *Teleosaurus*.

Order III. Ichthyopterygia.

This name, from ἰχθὺς, a fish, and πτέρυξ, a wing or fin, relates to the piscin character of the numerous and many-jointed rays or digits in the fore and hind paddles. The bones of the head still include the supplementary 'post-orbital' and 'supratemporal' bones, but there are small temporal and other vacuities between the cranial bones, including a 'foramen parietale;' there is a single, convex, occipital condyle*; and one vomer, which is edentulous. There are two antorbital nostrils. The vertebral centra are ossified and bi-concave. The pleurapophyses of the trunk are long and bent; the anterior ones with bifurcate heads. The teeth have converging folds of cement at their base, are implanted in a common alveolar groove, and are confined to the maxillary, premaxillary, and premandibular bones; the premaxillaries much exceeding the maxillaries in size. The orbits are very large; the eyes were defended by a broad circle of sclerotic plates. The limbs are natatory, with more than five multiarticulate digits; there is no sacrum.

With the retention of characters which indicate, as in the preceding orders, an affinity to the higher *Pisces Ganoidei*, the present exclusively marine *Reptilia* more directly exemplify the Ichthyic type in the proportions of the premaxillary and maxillary bones, in the shortness and great number of the bi-concave vertebræ, in the length of the pleurapophyses of the vertebræ near the head, in the large proportional size of the eye-ball and its well-ossified sclerotic coat, and especially in the structure of the pectoral and ventral fins.

Order IV. Sauropterygia.

The fins in this order of marine reptiles do not include more than five digits and resemble those of the turtles (*Chelone*) amongst existing Reptiles; hence the name proposed, from σαῦρος, a lizard, and πτέρυξ. There are no post-orbital and supratemporal bones†: the skull shows large temporal and other vacuities between certain cranial bones, including a foramen parietale: there are two antorbital nostrils: the teeth are simple, in distinct sockets of the premaxillary, maxillary, and premandibular bones: they are very rarely present on the palatine or pterygoid bones. The maxillaries are larger than the premaxillaries. Limbs natatory; with not more than five digits. There is a sacrum of one or two vertebræ for the attachment of the pelvic arch in some: there are numerous cervical vertebræ in most. The pleurapophyses have simple heads; those of the trunk are long and bent.

* This character is retained in all the subsequent orders except the *Batrachia*.

† These bones do not reappear in the subsequent orders.

In the *Pliosaurus* the neck-vertebræ are comparatively few in number, short, and flat. The Sauropterygian type seems to have attained its maximum dimensions in this genus, the species of which are peculiar to the Oxfordian and Kimmeridgian divisions of the Upper Oolitic system. The Polyptychodon of the cretaceous series also attained a gigantic size.

M. von Meyer regards the number of cervical vertebræ and the length of neck as characters of prime importance in the classification of *Reptilia*, and founds thereon his order called '*Macrotrachelen*,' in which he includes *Simosaurus*, *Pistosaurus*, and *Nothosaurus* with *Plesiosaurus*. No doubt the number of vertebræ in the same skeleton bears a certain relation to ordinal groups: the *Ophidia* find a common character therein: yet it is not their essential character; for the snake-like form, dependent on multiplied vertebræ, characterizes equally certain batrachians (*Cæcilia*) and fishes (*Muræna*). Certain regions of the vertebral column are the seat of great varieties, in the same natural group of *Reptilia*. We have long-tailed and short-tailed Lizards; but do not, therefore, separate those with numerous caudal vertebræ as 'Macroura' from those with few or none. The extinct *Dolichosaurus* of the Kentish chalk, with its procœlian vertebræ, cannot be ordinally separated, by reason of its more numerous cervical vertebræ, from other shorter-necked procœlian lizards. As little can we separate the short-necked and big-headed amplicœlian Pliosaur from the 'Macrotrachelians' of von Meyer, with which it has its most intimate and true affinities.

There is much reason indeed to suspect that some of the Muschelkalk Saurians, which are as closely allied to *Nothosaurus* as *Pliosaurus* is to *Plesiosaurus*, may have presented analogous modifications in the number and proportions of the cervical vertebræ. It is hardly possible to contemplate the broad and short-snouted skull of the *Simosaurus*, with its proportionately large teeth, without inferring that such a head must have been supported by a shorter and more powerful neck than that which bore the long and slender head of the *Nothosaurus* or *Pistosaurus*. The like inference is more strongly impressed upon the mind by the skull of the *Placodus*, still shorter and broader than that of *Simosaurus*, and with vastly larger teeth, of a shape indicative of their adaptation to crushing molluscous or crustaceous shells.

Neither the proportions and armature of the skull of *Placodus*, nor the mode of obtaining the food indicated by its cranial and dental characters, permit the supposition that the head was supported by other than a comparatively short and strong neck. Yet the composition of the skull, its zygomata, temporal cavities, and other light-giving anatomical characters, all bespeak the close essential relationship of *Placodus* to *Simosaurus* and other so-called 'Macrotrachelian' reptiles of the Muschelkalk-beds. I continue, therefore, as in my former 'Report' of 1841, to regard the fin-like modification of the limbs as a better ordinal character than the number of vertebræ in any particular region of the spine. Yet this limb-character is subordinate to the characters derived from the structure of the skull and of the teeth. If, therefore, the general term *Enaliosauria* may be sometimes found convenient in its application to the natatory group of Saurian Reptiles, the essential distinctness of the orders *Sauropterygia* and *Ichthyopterygia*, typified by the *Ichthyosaurus* and *Plesiosaurus* respectively, should be borne in mind.

The *Plesiosaurus*, with its very numerous cervical vertebræ, sometimes thirty in number, may be regarded as the type of the *Sauropterygia* or pentadactyle sea-lizards. Of all existing Reptiles, the lizards, and amongst these the Old-world Monitors (*Varanus*, Fitz.), by reason of the cranial vacuities in front of the orbits, most resemble the Plesiosaur in the structure of the skull, the division of the nostrils, the vacuities in the occipital region between the ex-occipitals and tympanics, the parietal foramen, the zygomatic extension of the post-frontal, the palato-maxillary and pterygo-sphenoid vacuities in the bony palate; and all these are Lacertian characters as contradistinguished from Crocodilian ones. But the antorbital vacuities between the nasal, pre-frontal, and maxillary bones, are the sole external nostrils in the Plesiosaurs: the zygomatic arch abuts against the fore part of the tympanic, and fixes it: a much greater extent of the roof of the mouth is ossified than in lizards, and the palato-maxillary and pterygosphenoid fissures are reduced to small size: the teeth, finally, are implanted in distinct sockets. That the Plesiosaur had the 'head of a lizard' is an emphatic mode of expressing the amount of resemblance in their cranial conformation: the crocodilian affinities, however, are not confined to the teeth, but are exemplified in some particulars of the structure of the skull itself.

In the simple mode of articulation of the ribs, the Lacertian affinity is again strongly manifested; but to this vertebral character such affinity is limited: all the others exemplify the ordinal distinction of the Plesiosaurs from known existing Reptiles. The shape of the joints of the centrums; the number of vertebræ between the head and tail, especially of those of the neck; the slight indication of the sacral vertebræ; the non-confluence of the caudal hæmapophyses with each other; are all 'plesiosauroid.' In the size and number of the abdominal ribs and sternum, may, perhaps, be discerned a first step in that series of development of the hæmapophyses of the trunk, which reaches its maximum in the plastron of the *Chelonia*.

The connation of the clavicle with the scapula is common to the *Chelonia* with the *Plesiosauri*; the expansion of the coracoid—extreme in *Plesiosauri*, —is greater in *Chelonia* than in *Crocodilia*, but is still greater in some *Lacertia*. The form and proportions of the pubis and ischium, as compared with the ilium, in the pelvic arch of the *Plesiosauri*, find their nearest approach in the pelvis of marine *Chelonia*; and no other existing Reptile now offers so near, although it be so remote, a resemblance to the structure of the paddles of the *Plesiosauri*.

Both *Nothosaurus* and *Pistosaurus* had many neck-vertebræ; and the transition from these to the dorsal series was effected, as in *Plesiosaurus*, by the ascent of the rib-surface from the centrum to the neurapophysis; but the surface, when divided between the two elements, projected further outwards than in most *Plesiosauri*.

In both *Notho-* and *Pisto-saurus*, the pelvic vertebra developes a combined process (par- and di-apophysis), but of relatively larger, vertically longer, size, standing well out, and from near the fore part of the side of the vertebra. This process, with the coalesced riblet, indicates a stronger ilium, and a firmer base of attachment of the hind limb to the trunk than in *Plesiosaurus*. Both this structure and the greater length of the bones of the fore-arm and leg show that the Muschelkalk predecessors of the Liassic *Plesiosauri* were better organized than they for occasional progression on dry land.

Order V. ANOMODONTIA*.

This order is represented by three families, all the species of which are extinct, and appear to have been restricted to the Triassic period. In it the teeth are wanting, or are confluent with tusk-shaped premaxillaries, or are confined to a single pair in the upper jaw having the form and proportions of canine tusks. The skull shows a 'foramen parietale' and two nostrils: the tympanic pedicle is fixed. The vertebræ are biconcave: the pleurapophyses

* *ἄνομος*, lawless; *ὀδοὺς*, tooth.

of the trunk are long and curved, the anterior ones having bifurcate heads: there is a sacrum of four or five vertebræ, forming, with broad iliac and pubic bones, a large pelvis. Limbs ambulatory.

Family *Dicynodontia* *.

A long ever-growing tusk in each maxillary bone: premaxillaries connate and forming with the lower jaw a beak-shaped mouth, probably sheathed with horn. This family includes two genera, *Dicynodon* and *Ptychognathus*, all the known species of which are founded on fossils from rocks of probably triassic age in South Africa.

Family *Cryptodontia* †.

Upper as well as lower jaw edentulous. The genus *Oudenodon* closely conforms to the Dicynodont type, and the species are from the same rocks and localities.

Family *Gnathodontia* ‡.

Two curved tusk-shaped bodies holding the place of the premaxillaries, and consisting of confluent dentinal and osseous substance, descending in front of the 'symphysis mandibulæ.' These bodies are homologous with the pair of confluent premaxillary teeth and bones in the existing New Zealand amphicœlian lizard *Rhynchocephalus*; they are analogous to the tusks in the *Dicynodonts*, and must have served a similar purpose in the extinct reptiles (*Rhynchosaurus*) of the New Red (Trias) Sandstone of Shropshire, in which alone, this structure, with an otherwise edentulous beak-shaped mouth, has hitherto been met with. The Rhynchosauroid reptile from the sandstone of Lossiemouth, near Elgin, is described by the Professor in the Government School of Mines, as having palatal teeth; but its close affinity to the Rhynchosaur of Shropshire adds to the probability of the triassic age of the Lossiemouth sandstone.

Order VI. Pterosauria §.

Although some members of the preceding order resembled birds in the shape or the edentulous state of the mouth, the reptiles of the present order make a closer approach to the feathered class in the texture and pneumatic character of most of the bones, and in the modification of the pectoral limbs for the function of flight. This is due to the elongation of the antibrachial bones, and more especially to the still greater length of the metacarpal and phalangial bones of the fifth or outermost digit, the last phalanx of which terminates in a point. The other fingers were of more ordinary length and size, and were terminated by claws, the number of their phalanges progressively increasing to the fourth, which had four joints The whole osseous system is modified in accordance with the possession of wings: the bones are light, hollow, most of them permeated by air-cells, with thin, compact outer walls. The scapula and coracoid are long and narrow, but strong. The vertebræ of the neck are few, but large and strong, for the support of a large head with long jaws, armed with sharp-pointed teeth. The skull was lightened by large vacuities, of which one was interposed between the nostril and the orbit. The vertebræ of the back are small, as are those of the sacrum, which were from two to five in number, but combined with a small pelvis and weak hind limbs, bespeaking a creature unable to stand and walk like a bird: the body must have been dragged along the ground like that of a bat. The vertebral bodies were united by ball-and-socket joints, the cup being

* δὶς, twice; κυνόδους, canine-tooth. † κρυπτὸς, concealed; ὀδοὺς, tooth.
‡ γνάθος, jaw; ὀδοὺς, tooth. § πτερὸν, wing; σαῦρος, lizard.

anterior; and in them we have the earliest manifestation of the 'procœlian' type of vertebra.

The Pterosauria are distributed into genera according to modifications of the jaws and teeth. In the oldest known species, from the Lias, the teeth are of two kinds; a few, at the fore part of the jaws, are long, large, sharp-pointed, with a full elliptical base, in distinct and separated sockets: behind them is a close-set row of short, compressed, very small, lancet-shaped teeth. These form the genus *Dimorphodon*, Ow.

In the genus *Rhamphorhynchus*, V. M., the fore part of each jaw is without teeth, and may have been encased by a horny beak; but behind the edentulous production there are four or five large and long teeth, on each side, followed by several smaller ones. The tail is long, stiff, and slender.

In the genus *Pterodactylus*, Cuv., the jaws are provided with teeth to their extremities: all the teeth are long, slender, sharp-pointed, set well apart. The tail is very short.

The *Pter. longirostris*, Ok., was about 10 inches in length; it is from lithographic slate at Pappenheim. The *Pter. crassirostris*, Goldf. was about 1 foot long; but the *Pter. Sedgwickii*, Ow., from the greensand, near Cambridge, had an expanse of wing of 20 feet. The above species exemplify the Pterodactyles proper.

The oldest well-known Pterodactyle is the *Dimorphodon macronyx*, of the lower lias; but bones of Pterodactyles have been discovered in coeval lias of Wirtemberg. The next in point of age is the *Dimorphodon Banthensis*, from the 'Posidonomyen-schiefer' of Banz in Bavaria, answering to the Alum-shale of the Whitby lias. Then follows the *Pt. Bucklandi* from the Stonesfield oolite. Above this, come the first-described and numerous species of Pterodactyle from the lithographic slates of the middle oolitic system, in Germany, and from Cirin on the Rhone. The Pterodactyles of the Wealden are, as yet, known to us by only a few bones and bone-fragments. The largest known species are the *Pterodactylus Sedgwickii* and *Pter. Fittoni*, from the Upper Greensand of Cambridgeshire. Finally, the Pterodactyles of the middle chalk of Kent, almost as remarkable for their great size, constitute the last forms of Flying Reptile known in the history of the crust of this earth.

Order VII. Thecodontia*.

The vertebral bodies are biconcave: the ribs of the trunk are long and bent, the anterior ones with a bifurcate head: the sacrum consists of three vertebræ: the limbs are ambulatory, and the femur has a third trochanter. The teeth have the crown more or less compressed, pointed, with trenchant and finely serrate margins; implanted in distinct sockets.

Teeth of this type, which may have belonged to the loricated saurian *Stagonolepis*, have been discovered by Mr. P. Duff in the white-sandstone at Lossiemouth near Elgin, affording additional evidence of its triassic age.

The *Protorosaurus* of the Permian Kupferschiefer of Thuringia appears to have had its teeth implanted in distinct sockets; but the neck-vertebræ resemble in their large and strong proportions those of the Pterodactyles; and the caudal vertebræ show the peculiarity, among Reptiles, of bifurcate neural spines. The types of the present order are the extinct genera *Thecodontosaurus* and *Palæosaurus* of Riley and Stutchbury, from probably triassic strata near Bristol; and the *Cladyodon* of the New Red sandstone of Warwickshire, with which, probably, the *Belodon* of the Keuper Sandstone of Wirtemberg is generically synonymous. The *Bathygnathus*, Leidy, from New Red sandstone of Prince Edward's Island, North America, is probably a

* θήκη, a case; ὀδοὺς, a tooth.

member of the present order, which seems to have been the forerunner of the next.

Order VIII. Dinosauria*.

Cervical and anterior dorsal vertebræ with par- and di-apophyses, articulating with bifurcate ribs: dorsal vertebræ with a neural platform: sacral vertebræ from four to six in number. The articular ends of the free vertebræ are more or less flat; but in the cervical become convex in front and concave behind, in some species. The limbs are ambulatory, strong, long and unguiculate. The femur has a third trochanter in some. The species of this order were of large bulk, and were eminently adapted for terrestrial life: some, *e.g.*, *Iguanodon* and probably *Hylæosaurus*, were more or less vegetable feeders; others, *e.g.*, *Megalosaurus*, were carnivorous. The Dinosaurs ranged, in time, from the lias (*Scelidosaurus*, Ow., from Charmouth) to the Upper Greensand (*Iguanodon*). The *Megalosaurus* occurs in the lower oolite to the Wealden inclusive. The latter formation is that in which the *Dinosauria* appear to have flourished in greatest numbers and of largest dimensions.

Order IX. Crocodilia.

Teeth in a single row, implanted in distinct sockets, external nostril single, and terminal or subterminal. Anterior trunk-vertebræ with par- and diapophyses, and bifurcate ribs; sacral vertebræ two, each supporting its own neural arch. Skin protected by bony, usually pitted, plates.

Suborder *Amphicœlia* †.

Crocodiles closely resembling in general form the long- and slender-jawed kind of the Ganges, called Gavial, existed from the time of the deposition of the lower lias. Their teeth were similarly long, slender, and sharp, adapted for the prehension of fishes, and their skeleton was modified for more efficient progress in water, by both the terminal vertebral surfaces being slightly concave, by the hind limbs being relatively larger and stronger, and by the orbits forming no prominent obstruction to progress through water. From the nature of the deposits containing the remains of the so-modified Crocodiles, they were marine. The fossil Crocodile from the Whitby Lias, described and figured in the 'Philosophical Transactions,' 1758, p. 688, is the type of these amphicœlian species. They have been grouped under the following generic heads:—*Teleosaurus*, *Mystriosaurus*, *Macrospondylus*, *Massospondylus*, *Pelagosaurus*, *Æolodon*, *Suchosaurus*, *Goniopholis*, *Pœcilopleuron*, *Stagonolepis*, &c. Species of the above genera range from the lias to the chalk inclusive.

Suborder *Opisthocœlia* ‡.

The small group of *Crocodilia*, so called, is an artificial one, based upon more or less of the anterior trunk-vertebræ being united by ball-and-socket joints, but having the ball in front, instead of, as in modern Crocodiles, behind. Cuvier first pointed out this peculiarity § in a crocodilian from the Oxfordian beds at Honfleur and the Kimmeridgian at Havre. The Reporter has described similar opisthocœlian vertebræ from the Great Oolite at Chipping Norton, from the Upper Lias of Whitby, and, of much larger size, from the Wealden formations of Sussex and the Isle of Wight. These specimens probably belonged, as suggested by him in 1841 and 1842 ||, to the fore part

* δεινὸς, terrible; σαῦρος, lizard.
† ἀμφί, both; κοῖλος, hollow: the vertebræ being hollowed at both ends.
‡ ὄπισθε, behind; κοῖλος, hollow: vertebræ concave behind, convex in front.
§ Annales du Muséum, tom. xii. p. 83. pl. xxi.
|| "Report on British Fossil Reptiles," Trans. British Association for 1841, p. 96.

of the same vertebral column as the vertebræ, flat at the fore part, and slightly hollow behind, on which he founded the genus *Cetiosaurus*. The smaller opisthocœlian vertebræ described by Cuvier have been referred by Von Meyer to a genus called *Streptospondylus*.

In one species of *Cetiosaurus* from the Wealden, dorsal vertebræ, measuring 8 inches across, are only 4 inches in length, and caudal vertebræ, nearly 7 inches across, are less than 4 inches in length; these characterize the species called *Cetiosaurus brevis*. Caudal vertebræ, measuring 7 inches across and $5\frac{1}{2}$ inches in length, from the Lower Oolite at Chipping Norton, and the Great Oolite at Enstone, represent the species called *Cetiosaurus medius*. Caudal vertebræ from the Portland Stone at Garsington, Oxfordshire, measuring 7 inches 9 lines across and 7 inches in length, have been referred to the *Cetiosaurus longus*; the latter appears to have been the most gigantic of Crocodilians.

Suborder *Procœlia**.

Crocodilians with cup-and-ball vertebræ like those of living species first make their appearance in the Greensand of North America (*Croc. basifissus* and *Croc. basitruncatus*)†. In Europe their remains are first found in the tertiary strata. Such remains from the plastic clay of Meudon have been referred to *Crocodilus isorhynchus*, *Croc. cœlorhynchus*, and *Croc. Becquereli*. In the 'Calcaire grossier' of Argenton and Castelnaudry have been found the *Croc. Rallinati* and *Croc. Dodunii*. In the coeval eocene London Clay at Sheppey Island, the entire skull and characteristic parts of the skeleton of *Crocodilus toliapicus* and *Croc. Champsoides* occur. In the somewhat later eocene beds at Bracklesham occur the remains of the Gavial-like *Croc. Dixoni*. In the Hordle upper eocene beds have been found the *Crocodilus Hastingsiæ* with short and broad jaws; and also a true Alligator (*Croc. Hantoniensis*). It is remarkable that forms of procœlian *Crocodilia*, now geographically restricted—the Gavial to Asia, and the Alligator to America,—should have been associated with true Crocodiles, and represented by species which lived during nearly the same geological period, in rivers flowing over what now forms the south coast of England.

Many species of procœlian *Crocodilia* have been founded on fossils from miocene and pliocene tertiaries. One of these, of the Gavial subgenus (*Croc. crassidens*) from the Sewalik tertiary, was of gigantic dimensions.

Order X. Lacertilia.

Vertebræ procœlian, with a single transverse process on each side, and with single-headed ribs: sacral vertebræ not exceeding two.

Small vertebræ of this type have been found in the Wealden of Sussex. They are more abundant, and are associated with other and more characteristic parts of the species in the Cretaceous strata. On such evidence have been based the *Raphiosaurus subulidens*, the *Coniosaurus crassidens*, and the *Dolichosaurus longicollis*. But the most remarkable and extreme modification of the Lacertian type in the Cretaceous period is that manifested by the huge species, of which a cranium, 5 feet long, was discovered in the Upper Chalk of St. Peter's Mount, near Maestricht, in 1780. This species, under the name *Mosasaurus*, is well known by the descriptions of Cuvier. Allied species have been found in the cretaceous strata of England and N. America. The *Leiodon anceps* of the Norfolk chalk was a nearly allied marine Lacertian. The structure of the limbs is not yet well understood; it may lead to a subordinal separation of the Mosasauroids from the Land-lizards, most of which

* πρὸ, before; κοῖλος, hollow: vertebræ with the cup at the fore part and the ball behind.

† Quarterly Journal of the Geological Society, January, 1849, p. 380.

are represented by existing species, in which a close transition is manifested to the next order.

Order XI. Ophidia *.

Vertebræ very numerous, procœlian, with a single transverse process on each side; no sacrum: no visible limbs.

The earliest evidence, at present, of this order is given by the fossil vertebræ of the large serpent (*Palæophis*, Ow.) from the London clay of Sheppey and Bracklesham. Remains of a poisonous serpent, apparently a *Vipera*, have been found in miocene deposits at Sansans, S. of France. A large fossil serpent (*Laophis*, Ow.), with vertebræ showing similar modifications to those in the Crotali, has been discovered by Capt. Sprat, R.N., in a tertiary formation at Salonica. Ophidiolites from Œningen have been referred to the genus *Coluber*.

Order XII. Chelonia †.

The characters of this order, including the extremely and peculiarly modified forms of Tortoises, Terrapenes, and Turtles, are sufficiently well known.

The chief modifications of osseous structure in oolitic Chelonia are shown by the additional pair of bones interposed between the hyosternals and hyposternals of the plastron, in the genus *Pleurosternon* from the upper oolite at Purbeck. It would be very hazardous to infer the existence of Reptiles with the characteristic structure of the restricted genus *Testudo* from the foot-prints in the triassic sandstone of Dumfriesshire. But the Reporter concurs in the general conclusions based upon the admirable figures and descriptions in the splendid monograph by Sir Wm. Jardine, Bart., F.L.S., that some of those foot-prints most probably belonged to species of the Chelonian order.

An enormous species of true turtle (*Chelone gigas*), the skull of which measured one foot across the back part, has left its remains in the eocene clay at Sheppey. The terrestrial type of the order had been exemplified on a still more gigantic scale by the *Colossochelys* of the Sewalik tertiaries.

Order XIII. Batrachia ‡.

Vertebræ biconcave (*Siren*), procœlian (*Rana*), or opisthocœlian (*Pipa*); pleurapophyses short, straight. Two occipital condyles and two vomerine bones, in most dentigerous: no scales or scutes. Larvæ with gills, in most deciduous. Representatives of existing families or genera of true Batrachia have been found fossil, chiefly in tertiary and post-tertiary strata. Indications of a perennibranchiate batrachian have recently been detected by the Reporter in a collection of minute Purbeck fossils. Anourous genera (*Palæophrynus*) allied to the Toad occur in the Œningen tertiaries, and here also the remains of the gigantic Salamander (*Andrias Scheuchzeri*) were discovered.

Summary of the above defined Orders.

Province VERTEBRATA.

Class Hæmatocrya. Sub-class Reptilia.

Orders.

I. Ganocephala.	VIII. Dinosauria.
II. Labyrinthodontia.	IX. Crocodilia.
III. Ichthyopterygia.	X. Lacertilia.
IV. Sauropterygia.	XI. Ophidia.
V. Anomodontia.	XII. Chelonia.
VI. Pterosauria.	XIII. Batrachia.
VII. Thecodontia.	

* ὄφις, a serpent. † χελώνη, a tortoise. ‡ βάτραχος, a frog.

On some Results of the Magnetic Survey of Scotland in the years 1857 *and* 1858, *undertaken, at the request of the British Association, by the late* JOHN WELSH, *Esq., F.R.S. By* BALFOUR STEWART, *A.M.*

THE much-lamented death of Mr. Welsh, who laboured in science so well and so earnestly, and the last work of whose life was the completion of the observations of the Magnetic Survey of Scotland, has imposed upon the author the less arduous task of reducing those observations.

It is now somewhat more than twenty years since the first Magnetic Survey of the British Islands was made, the results of which are recorded by General Sabine in the Report of the British Association for 1838.

The General Committee at the Meeting held at Cheltenham in 1856, feeling that the time had arrived when another survey of these islands would be desirable, requested General Sabine, Prof. Phillips, Sir James C. Ross, Mr. Robert W. Fox, and Rev. Dr. Lloyd, to undertake its repetition. It was ultimately resolved that Mr. Welsh should proceed to Scotland, and the Admiralty kindly granted £200 in aid of his expenses.

During the summer and autumn of 1857 Mr. Welsh performed the first instalment of his task, confining himself to stations in the interior of Scotland and on the east coast. In the same season of 1858 he completed the survey, by undertaking the west coast, the Hebrides, and the Orkney and Shetland Isles. This involved much personal fatigue and a great number of observations, all of which were executed with the utmost possible accuracy and scientific attention to details.

More was done for Scotland in this survey than in that of twenty years ago. In the interval between the two surveys, improvements had been made in the dip-circle and in the apparatus for measuring the total magnetic force. These improvements were of course adopted in the instruments employed in the late survey; and, furthermore, observations of declination were made,—a thing which had not been previously attempted. The survey thus divides itself into three parts: the first comprising the Observations of Dip; the second those of Total Force; and the third those of Declination, which will be discussed in order.

DIVISION I.—*Dip.*

The dip-circle (No. 23) was made by Barrow. Two needles were employed, each $3\frac{1}{2}$ inches long. The axle of the needle rests on two agate planes, and its position is concentric with, but behind (as regards the observer) the vertical divided circle on which the inclination is read. A moveable arm, concentric with this circle, has two microscopes attached to it, the distance between them being $3\frac{1}{2}$ inches, so that either extremity of the needle may be brought into the centre of the field of the corresponding microscope. The extremities of this moveable arm form verniers which bear upon the vertical circle, and by means of which the position of the needle may be very accurately determined. In November 1857, the following observations were made with this instrument in different azimuths :—

Table I.

Needle.	Magnetic azimuth.	End A dipping.	End B dipping.	Mean.	Resulting dip.
1	0°	68° 27′·37	68° 25′·25	68° 26′·31	68° 26′·31
	30	71 7·12	71 6·00	71 6·56	68 26·75
	120	78 50·75	78 49·50	78 50·12	
	60	78 52·50	78 52·00	78 52·25	68 25·58
	150	71 6·12	71 2·12	71 4·12	
2	0	68 24·12	68 29·00	68 26·56	68 26·56
	30	71 3·00	71 9·37	71 6·18	68 25·07
	120	78 48·25	78 45·75	78 47·00	
	60	78 44·87	78 51·62	78 48·25	68 25·00
	150	71 4·00	71 7·25	71 5·62	

In this Table the resulting dips are calculated by the formula $\cot^2\delta=\cot^2 i+\cot^2 i'$, where δ is the true dip, and i and i' the positions of the needle in azimuths 90° apart.

These results are satisfactory, and show that any errors due to the axle or to local magnetism in the circle are inappreciable throughout the range of observation: otherwise we should have had greater differences in the resulting dips. Now the portion of the circle so tested comprehends that used during the magnetic survey; we may therefore with safety suppose the circle to be free from magnetism and error of axle as far as the results of the survey are concerned. It will also be observed that the dips given by both needles are very nearly the same; and although this amount of agreement did not always hold throughout the survey, yet the average difference between the needles is exceedingly small. It has therefore been thought unnecessary to apply any correction in the case of those stations (very few in number) where only one needle was observed.

The following Table exhibits the results of a comparison made at Kew Observatory between the Survey dip-circle (No. 23) and other reliable instruments, in March 1859:—

Table II.

Circle.	Needle.	Number of observations.	Dip.	Mean of both needles.
No. 20	1	4	68° 23′·00	68° 23′·87
,,	2	4	68 24·74	
33	1	4	68 23·26	68 22·42
,,	2	4	68 21·58	
34	1	4	68 22·17	68 21·07
,,	2	4	68 19·97	
23	1	2	68 24·78	68 23·52
,,	2	2	68 22·26	
30	1	2	68 21·68	68 22·50
,,	2	2	68 23·32	
Kew	1	3	68 20·88	68 21 76
,,	2	3	68 22·64	
		Mean of all circles		68 22·5

It appears from this Table, that, while the mean of all the circles gives a dip of 68° 22′·5, the observations with circle No. 23 give 68° 23′·5, or 1′ higher. This difference is so small, that it has been thought unnecessary to apply any constant correction to the dips on account of it. It is therefore presumed that circle No. 23 is calculated to exhibit the true dip at the place of observation.

An equal weight has been attached to each of the mean dips obtained at the various stations, without regard to the number of observations made at any station, in accordance with a remark of General Sabine, that an abnormal result is more likely to be due to local magnetism than to error in observing.

The dips have been corrected for secular change to the epoch of 1st January, 1858. The yearly rate of change has been ascertained by comparing the observations of the present with those of the previous survey. The method is exhibited in the following Table :—

TABLE III.

Station.	First Dip.	Date of First Dip.	Second Dip.	Date of Second Dip.	Difference of Dips.	Difference of dates in years.	Yearly rate of decrease.
	° ′		° ′				′
Lerwick	73 44·9	1838	73 11·9	1858	33·0	20	1·65
Aberdeen	72 27·6	1838	71 49·3	1857	38·3	19	2·02
Kirkwall	73 20·4	1838	72 40·9	1858	39·5	20	1·97
Wick	73 19·9	1838	72 39·5	1858	40·4	20	2·02
Golspie	72 55·5	1836	72 25·0	1858	30·5	22	1·39
	73 4·3	1838	72 25·0	1858	39·3	20	1·96
Inverness	72 46·4	1836	72 7·9	1857	38·5	21	1·83
	72 46·2	1838	72 7·9	1857	38·3	19	2·01
Fort Augustus	72 40·3	1836	72 2·6	1857	37·7	21	1·80
Berwick	71 41·9	1838	70 54·8	1857	47·1	19	2·48
Melrose	71 36·8	1836	70 54·7	1857	42·1	21	2·00
	71 38·0	1837	70 54·7	1857	43·3	20	2·16
Alford	72 21·9	1836	71 45·9	1857	36·0	21	1·71
Gretna	71 29·0	1837	70 46·0	1857	43·0	20	2·15
Edinburgh	71 50·3	1836	71 11·2	1857	39·1	21	1·86
	71 50·0	1837	71 12·5	1858	37·5	21	1·79
Glasgow	72 1·6	1836	71 26·3	1857	35·3	21	1·68
	72 5·0	1837	71 26·3	1857	38·7	20	1·93
Helensburgh	72 16·7	1836	71 29·6	1857	47·1	21	2·24
	72 17·0	1838	71 29·6	1857	47·4	19	2·49
Campbelton	71 55·9	1836	71 14·0	1857	41·9	21	1·99
Cumbray	72 1·1	1836	71 28·9	1857	32·2	21	1·53
	Mean annual rate of decrease = 1·94						

In reducing the dips to the epoch, a yearly rate of decrease of 1′·94, or in round numbers 2′, has accordingly been adopted. No other correction has been applied to the observations. They are thus presented to our view in the following Table :—

TABLE IV.

Station.	Date.	Greenwich Mean time of Observation.	Needle.	Pole A.	Pole B.	Mean of both Poles.	Mean at the Station.	Dip reduced to epoch Jan. 1, 1858.	Place of Observation.
	1857.	h m							
Berwick	Aug. 8	10 27 A.M.	1	70° 56′·44	70° 55′·00	70° 55′·72	70° 51′·8	70° 54′·0	
	8	0 50 P.M.	2	70 54·62	70 53·00	70 53·82			
Makerstoun	10	10 28 A.M.	1	70 51·50	70 50·75	70 51·12	70 50·3	70 49·5	Observatory.
	10	11 20 ,,	2	70 46·12	70 50·42	70 48·27			
	11	11 14 ,,	2	70 50·75	70 52·50	70 51·62			
Melrose	12	6 15 P.M.	1	70 54·37	70 55·12	70 54·75	70 54·7	70 53·9	200 yards East of the Abbey.
	12	7 46 ,,	2	70 56·37	70 52·75	70 54·56			
Edinburgh	13	1 42 ,,	1	71 10·41	71 11·42	71 10·95	71 10·9	71 10·1	Botanic Gardens.
Carstairs	14	0 12 ,,	1	70 55·75	70 56·87	70 56·31	70 56·3	70 55·5	500 yards S.W. of Junction Station, in Mr. Monteith's grounds.
Gretna	15	10 13 A.M.	1	70 46·25	70 45·69	70 45·97	70 46·0	70 45·2	150 yards in front of Hotel, about half a mile W.S.W. of Gretna Caledonian Railway Station.
Dumfries	17	10 40 A.M.	1	70 46·06	70 44·75	70 45·40	70 43·8	70 43·2	Mr. Stott's farm, Lower Netherwood.
	17	0 26 P.M.	2	70 41·87	70 42·50	70 42·18			
Newton Stewart	18	6 17 ,,	2	70 52·75	70 52·87	70 52·81	70 54·4	70 53·8	300 yards N.N.W. of Parish Church.
	19	9 56 A.M.	1	70 57·00	70 55·12	70 56·06			
Stranraer	20	0 12 P.M.	1	70 55·87	70 54·37	70 55·12	70 55·4	70 54·8	200 yards W.N.W. of Schenchan Church.
	20	1 55 ,,	2	70 55·37	70 55·87	70 55·62			
Ayr	22	9 2 A.M.	1	71 7·50	71 5·00	71 6·25	71 5·8	71 5·2	On the Common, about 150 yards S. of the Court House.
	22	11 17 ,,	2	71 3·69	71 6·94	71 5·31			
Glasgow	24	11 1 ,,	1	71 27·37	71 25·69	71 26·53	71 26·3	71 25·7	Botanic Gardens.
	24	11 53 ,,	2	71 26·12	71 28·19	71 27·15			
	24	3 0 P.M.	1	71 24·50	71 25·75	71 25·12			
Lamlash	25	3 5 ,,	1	71 6·00	71 8·00	71 7·00	71 6·3	71 5·7	
	25	4 47 ,,	2	71 7·25	71 4·12	71 5·68			
Brisbane	26	3 14 ,,	1	71 31·00	71 34·12	71 32·56	71 32·6	71 32·0	Observatory.
Cumbray	27	2 34 ,,	1	71 29·12	71 28·75	71 28·94	71 28·9	71 28·3	N.E. end of Great Cumbray, within 30 yards of sea.
Helensburgh	28	2 30 ,,	1	71 27·62	71 28·25	71 27·93	71 27·9	71 27·3	Avenue magnetic E. of Mr. Smith's house.
Loch Goilhead	29	6 14 ,,	1	71 16·37	71 18·00	71 17·19	71 17·2	71 16·6	150 yards behind the Church.
Campbelton	Sept. 1	1 18 ,,	1	71 11·19	71 13·12	71 12·15	71 13·9	71 13·3	200 yards N.E. from lime crags, 400 yards E.S.E. from old Parish Church.
	1	2 3 ,,	2	71 17·12	71 14·25	71 15·68			
Helensburgh	3	11 20 A.M.	1	71 26·12	71 31·12	71 28·62	71 30·4	71 29·8	Avenue magnetic East of Mr. Smith's House.
	3	2 40 P.M.	2	71 32·94	71 31·38	71 32·16			
Ardrishaig	4	6 04 ,,	1	71 26·94	71 23·69	71 25·31	71 25·8	71 25·2	80 yards West end of Crinan Canal Basin.
	4	6 44 ,,	2	71 27·62	71 25·00	71 26·31			

Oban		7	1 15 „	1	71 32·06	71 31·31	71 31·68	71 29·9	71 29·3	400 yards North of Steam-boat pier.
		7	3 10 „	2	71 24·87	71 31·50	71 28·18			80 yards S.E. of Donolly Lodge Gate.
Corpach		8	11 30 A.M.	1	71 54·37	71 55·31	71 54·84	71 53·3	71 52·7	The dip and intensity observed on south bank of canal 400 yards below Neptune's Staircase; the declination in front of Banavie Inn.
		8	3 27 P.M.	2	71 49·50	71 53·87	71 51·68			
Fort Augustus		9	5 17 „	1	72 4·75	72 1·25	72 3·00	72 2·6	72 2·0	35 yards S.E. (magnetic) of Parish Church,
		9	6 39 „	2	72 0·37	72 4·12	72 2·25			400 yards W. by N. (magnetic) of Fort.
Inverness		11	4 7 „	1	72 10·19	72 5·81	72 8·00	72 7·9	72 7·3	In garden of Mr. Mitchell near the Castle of Inverness.
		11	5 32 „	2	72 6·75	72 9·00	72 7·87			
Elgin		14	5 33 „	1	72 9·50	72 7·12	72 8·31	72 8·3	72 7·7	Hotel garden, 100 yards south of steeple.
Banff		15	6 12 „	1	71 56·43	71 54·87	71 55·65	71 56·5	71 55·9	In front of Mr. Bremner's house in the grounds of the old Castle of Banff.
		16	9 21 A.M.	2	71 55·62	71 59·06	71 57·34			
Peterhead		17	10 1 „	1	71 56·38	71 55·69	71 56·03	71 54·7	71 54·2	½ mile west of Church, in an old garden.
		17	11 57 „	2	71 53·94	71 52·87	71 53·40			
Aberdeen		19	1 55 P.M.	1	71 51·69	71 47·12	71 49·40	71 49·4	71 48·9	1 mile south of Marischal College.
		19	3 16 „	2	71 48·62	71 50·00	71 49·31			
Kintore		21	2 19 „	2	71 37·81	71 35·75	71 36·78	71 36·8	71 36·3	
Alford		22	11 38 A.M.	1	71 48·31	71 45·50	71 46·90	71 45·9	71 45·4	In front of the Manse.
		22	1 20 P.M.	2	71 43·75	71 46·12	71 44·93			
Braemar		24	10 56 A.M.	1	71 31·37	71 32·12	71 31·75	71 31·3	71 30·8	10 yards in front of Invercauld Arms Inn, in grounds of Church.
		24	1 3 P.M.	2	71 29·75	71 32·00	71 30·87			
Pitlochry		26	0 22 „	1	71 36·12	71 34·44	71 35·28	71 35·3	71 34·8	Dysart Cottage, 60 yards to mag. N.; Inn 400 yards to magnetic S.E.
Dalwhinnie		29	11 1 A.M.	1	71 42·75	71 37·81	71 40·28	71 39·5	71 39·0	Field 150 yards west of the Inn.
		29	1 6 P.M.	2	71 37·37	71 40·25	71 38·81			
Larbert	Oct.	1	0 37 „	1	71 34·75	71 32·56	71 33·65	71 33·5	71 33·0	
		1	2 17 „	2	71 32·25	71 34·25	71 33·25			
Edinburgh		5	1 0 „	1	71 16·25	71 9·25	71 12·75	71 11·3	71 10·8	Botanic Gardens.
	1858.	5	3 20 „	2	71 7·37	71 12·37	71 9·87			
Makerstoun	July	5	0 7 P.M.	1	70 49·94	70 45·25	70 47·60	70 49·8	70 50·8	Observatory.
		5	1 2 „	2	70 51·19	70 50·44	70 50·81			
		6	0 7 „	2	70 51·62	70 53·50	70 52·56			
		6	0 37 „	1	70 47·00	70 49·37	70 48·18			
Edinburgh		8	0 22 „	2	71 13·00	71 12·87	71 12·94	71 12·5	71 13·5	Botanic Gardens.
		10	10 27 A.M.	1	71 13·12	71 11·12	71 12·12			
Ardrossan		12	10 16 „	2	71 16·87	71 17·00	71 16·94	71 13·5	71 14·5	Half a mile (true) north of Harbour.
		12	10 56 „	1	71 8·50	71 11·62	71 10·06			
Port Askeg		16	1 8 P.M.	2	71 16·00	71 16·37	71 16·19	71 13·5	71 14·6	
		16	2 56 „	1	71 9·87	71 11·87	71 10·87			
Bridgend		19	11 28 A.M.	2	71 16·00	71 18·12	71 17·06	71 14·9	71 16·0	
		19	1 46 P.M.	1	71 10·75	71 14·62	71 12·68			
Port Ellen		21	1 46 „	2	71 5·37	71 6·87	71 6·12	71 4·1	71 5·2	
		21	2 16 „	1	71 6·37	70 58·00	71 2·18			

TABLE IV. (*continued.*)

Station.	Date.	Greenwich Mean time of Observation.	Needle.	Pole A.	Pole B.	Mean of both Poles.	Mean at the Station.	Dip reduced to epoch Jan. 1, 1858.	Place of Observation.
	1858.	h m							
Tobermorie	July 24	3 25 P.M.	2	72° 46′·00	72° 47′·62	72° 46′·81	72° 46′·8	72° 47′·9	
Glenmorven	26	11 7 A.M.	2	72 5·00	72 7·25	72 6·12	72 2·1	72 3·2	
	26	1 55 P.M.	1	71 59·12	71 57·00	71 58·06			
Balmacarra	28	11 10 A.M.	2	72 12·75	72 13·50	72 13·12	72 12·7	72 13·8	
	28	11 37 ,,	1	72 12 50	72 12·00	72 12·25			
Kyleakin	29	2 57 P.M.	2	72 12·37	72 16·25	72 14·31	72 10·6	72 11·7	
	29	6 17 ,,	1	72 9·25	72 4·50	72 6·87			
Broadford	30	3 50 ,,	2	72 10·25	72 14·50	72 12·37	72 15·7	72 16·8	
	30	4 20 ,,	1	72 20·00	72 11·37	72 15·68			
	31	11 45 A.M.	1	72 23·18	72 13·37	72 18·27			
	31	0 30 P.M.	2	72 10·62	72 22·31	72 16·46			
Portree	Aug. 3	3 44 ,,	2	71 59·50	72 3·75	72 1·62	72 1·2	72 2·3	
	3	4 20 ,,	1	72 3·81	71 57·94	72 0·87			
Stornoway	5	3 41 ,,	2	72 32·00	72 35·31	72 33·65	72 32·6	72 33·7	In dell near Bridge in grounds of Castle 400 yards magnetic East of Castle.
	5	4 20 ,,	1	72 32·68	72 31·94	72 32·31			
	6	0 50 ,,	1	72 33·37	72 30·06	72 31·72			
	6	1 31 ,,	2	72 30·37	72 34·75	72 32·56			
Callinish	9	4 4 ,,	2	72 32·62	72 37·62	72 35·12	72 34·1	72 35·2	
	9	4 46 ,,	1	72 36·62	72 29·44	72 33·03			
Cross	11	10 55 A.M.	2	72 49·50	72 52·50	72 51·00	72 49·1	72 50·2	In front of the manse.
	11	2 2 P.M.	1	72 50·37	72 44·12	72 47·25			
Loch Inver	16	11 0 A.M.	1	72 38·12	72 34·50	72 36·31	72 35·6	72 36·9	
	16	3 43 P.M.	2	72 34·62	72 35·18	72 34·90			
Durness	18	3 41 ,,	2	72 50·12	72 52·50	72 51·31	72 50·0	72 51·3	Inn.
	19	0 12 ,,	1	72 50·37	72 47·18	72 48·78			
Thurso	23	10 45 A.M.	2	72 34·18	72 34·68	72 34·43	72 32·7	72 34·0	In field behind Royal Hotel, 200 yards E. of Church.
	23	2 58 P.M.	1	72 34·06	72 27·87	72 30·96			
Stromness	25	10 13 A.M.	1	72 49·18	72 41·75	72 45·46	72 45·5	72 46·8	
Lerwick	30	10 39 ,,	2	73 12·37	73 16·18	73 14·28	73 11·9	73 13·2	¼ mile magnetic S. of middle of town.
	30	3 6 P.M.	1	73 12·75	73 6·31	73 9·53			
Kirkwall	31	0 48 ,,	2	72 42·18	72 43·44	72 42·81	72 40·9	72 42·2	
	31	3 15 ,,	1	72 39·94	72 38·06	72 39·00			
Wick	Sept. 4	0 10 ,,	2	72 40·44	72 42·25	72 41·34	72 39·5	72 40·8	Observed on the lawn in front of Rosebank (Jas. Henderson, Esq.).
	4	2 43 ,,	1	72 38·00	72 37·31	72 37·65			
Golspie	7	11 43 A.M.	2	72 23·68	72 27·81	72 25·74	72 25·0	72 26·3	
	7	0 33 P.M.	2	72 23·37	72 25·25	72 24·31			
Dingwall	9	11 4 A.M.	2	72 22·37	72 26·62	72 24·50	72 24·5	72 25·8	Within 500 yards of the Church.

It is now necessary that these observations be combined together by the method of least squares. This method is described by General Sabine, in discussing the Magnetic Observations in Scotland, in the volume of Reports of the British Association for 1836.

We are thus enabled to determine the most probable values of three unknown quantities; viz. of δ=the dip at the central position; u=the angle which the isoclinal line passing through the central position makes with the meridian; and r=the coefficient, determining the rate of increase of the dip in the normal direction, or that direction which is at right angles to the isoclinal lines.

Using all the stations except Tobermorie (where the dip seems to be much increased by local attraction), we obtain the following values of δ, u and r; $\delta=71^\circ{\cdot}45'$, which represents the most probable value of the dip at the central station, lat. 56° 48′ N., long. 4° 19′ W.; u, or the angle which the isoclinal line makes with the meridian, $=-71^\circ\ 29'$, or its direction is from N. 71° 29′ E. to S., 71° 29′ W.; and r, or the rate of increase of dip in the normal direction, $=0'{\cdot}556$ for each geographical mile, or 53·95 such miles for each half degree of dip.

The dip observations made use of in the previous survey of twenty years ago consist of two sets (see Eighth Report of British Association, pp. 88–90).

1. Observations were made at ten stations by Sir James Ross; these give $\delta=72^\circ\ 40'{\cdot}8$ at the mean geographical position, 57° 20′ N., and 3° 08′ W., and at the mean epoch, August 18, 1838; also $u=-62^\circ\ 39'$; $r=0'{\cdot}545$.

2. Observations were made at thirty-six stations by General Sabine and Mr. Fox; these give $u=-54^\circ\ 20'$; $r=0'{\cdot}550$; $\delta=72^\circ\ 13'{\cdot}2$ at the mean geographical position 56° 18′ N., and 4° 10′ W. at the epoch, September 1, 1836.

Let us regard these results as each possessing a weight proportional to the number of stations made use of in obtaining it, and let us reduce them to the epoch 1st January, 1837, by assuming the approximate yearly decrement of dip to be 2′, and the similar increment of the angle $-u$ to be 44′; also let us reduce δ to the central station, lat. 56° 48′ N., long. 4° 19′ W.

This station being the same as that used in the present survey, we have thus the means of comparing the results of both surveys in the following Table:—

TABLE V.

Central Station.					
Lat.	Long.	Epoch.	δ.	u.	r.
56° 48′ N.	4° 19′ W.	1 Jan. 1837	72° 31′·9	−56° 03′	0′·550
56 48 N.	4 19 W.	1 Jan. 1858	71 45·0	−71 29	0·556

We thus see that in twenty-one years the dip at the central station has diminished 46′·9, or its yearly rate of decrease is 2′·23; the value of $-u$, on the other hand, has been increased by 15° 26′, or the isoclinal lines are so much more nearly horizontal than they were in 1837; while r, or the coefficient which denotes the change of dip in a normal direction, has altered very little*.

* These changes will be rendered obvious by referring to a map appended to this Report (Plate 6), in which the isoclinal lines for the two surveys are compared together.

It has already been remarked, that the difference between the observed and calculated dip for a station is more likely to be due to local attraction than to error of observation. Local attraction, again, may be presumed to depend on the geological formation of the neighbourhood. In the following Table the difference between the observed and calculated dips is compared with the geological character of the station.

In this Table, the latitudes and longitudes, unless when the contrary is specified, are obtained from a Map of Scotland published by the Society for the Diffusion of Useful Knowledge, while the geological character of the station is obtained from Prof. Phillips' Geological Map of Great Britain and Ireland.

TABLE VI.

Station.	Lat.	Long.	Observed Dip reduced to epoch.	Dip calculated by least squares.	Observed minus calculated Dip.	Geological character of station.
Berwick	55° 46′	2° 00′	70° 54′·0	70° 58′·4	− 4′·4	Clay-slate.
†Makerstoun	55 35	2 31	70 55·2	70 55·7	− 5·5	Felspathic trap.
Melrose	55 35	2 44	70 53·9	70 57·0	− 3·1	Soft clay-slate.
†Edinburgh	55 58	3 11	71 11·5	71 11·9	− 0·4	Coal series.
Carstairs	55 43	3 40	70 55·5	71 06·8	−11·3	Coal.
Gretna	55 01	3 03	70 45·2	70 40·9	+ 4·3	New Red sandstone.
Dumfries	55 05	3 36	70 43·2	70 46·3	− 3·1	Ditto.
Newton Stewart	54 56	4 28	70 53·8	70 46·9	+ 6·9	Soft clay-slate.
Stranraer	54 54	5 02	70 54·8	70 49·1	+ 5·7	Ditto.
Ayr	55 28	4 38	71 05·2	71 04·6	+ 0·6	Coal.
†Glasgow	55 52	4 16	71 25·7	71 15·1	+10·6	Ditto.
Lamlash	55 31	5 05	71 05·7	71 09·0	− 3·3	Old Red sandstone and trap.
†Brisbane	55 49	4 52	71 32·0	71 17·0	+15·0	Ditto, ditto.
Cumbray	55 48	4 52	71 28·3	71 16·6	+11·7	Old Red sandstone.
Helensburgh	56 02	4 43	71 28·5	71 23·0	+ 5·5	Mica schist.
‡Lochgoilhead	56 10	4 54	71 16·6	71 28·3	−11·7	Ditto.
Campbelton	55 25	5 41	71 13·3	71 09·4	+ 3·9	Old Red sandstone and mica schist associated with primary limestone.
‡Ardrishaig	56 01	5 27	71 25·2	71 26·9	− 1·7	Chlorite slate.
Oban	56 27	5 26	71 29·3	71 40·4	−11·1	Trap and Old Red sandstone.
Corpach	56 51	5 08	71 52·7	71 51·3	+ 1·4	Granite and gneiss.
Fort Augustus	57 09	4 40	72 02·0	71 58·0	+ 4·0	Mica schist.
Inverness	57 28	4 11	72 07·3	72 05·2	+ 2·1	Old Red sandstone.
Elgin	57 39	3 19	72 07·7	72 06·2	+ 1·5	Ditto, and oolite.
Banff	57 39	2 31	71 55·9	72 01·6	− 5·7	Gneiss and granite.
Peterhead	57 31	1 46	71 54·2	71 53·2	+ 1·0	Granite.
Aberdeen	57 09	2 05	71 48·9	71 43·1	+ 5·8	Ditto.
Kintore	57 15	2 23	71 36·3	71 48·1	−11·8	Ditto, and gneiss.
Alford	57 14	2 45	71 45·4	71 49·7	− 4·3	Gneiss.
Braemar	57 01	3 25	71 30·8	71 46·5	−15·7	Ditto.
‡Pitlochry	56 42	3 43	71 34·8	71 38·3	− 3·5	Mica schist and gneiss.
Dalwhinnie	56 56	4 17	71 39·0	71 49·0	−10·0	Gneiss.
Larbert	56 02	3 49	71 33·0	71 17·8	+15·2	Coal.
Ardrossan	55 39	4 47	71 14·5	71 11·3	+ 3·2	Ditto.
Port Askeg	55 52	6 08	71 14·6	71 26·2	−11·6	Mica schist.
Bridgend	55 48	6 16	71 16·0	71 24·8	− 8·8	
Port Ellen	55 40	6 10	71 05·2	71 20·1	−14·9	Ditto.

† Determined by astronomical observations.
‡ Obtained through the kindness of Colonel James.

TABLE VI. (*continued.*)

Station.	Lat.	Long.	Observed Dip reduced to epoch.	Dip calculated by least squares.	Observed minus calculated Dip.	Geological character of station.
Tobermorie	56 39	6 02	72 47·9	71 50·1	+57·8	Trap.
Glenmorven	56 38	5 58	72 03·2	71 49·2	+14·0	Ditto.
‡Balmacarra	57 17	5 39	72 13·8	72 7·9	+ 5·9	Gneiss associated with quartz and Old Red sandstone.
‡Kyleakin	57 16	5 44	72 11·7	72 7·9	+ 3·8	Old Red sandstone.
Broadford	57 15	5 51	72 16·8	72 8·0	+ 8·8	Trap and lias.
Portree	57 26	6 12	72 02·3	72 15·8	−13·5	Oolite and trap.
Stornoway.........	58 15	6 23	72 33·7	72 42·3	− 8·6	Gneiss.
*Callinish	58 10	6 44	72 35·2	72 41·6	− 6·4	Ditto.
*Cross	58 29	6 17	72 50·2	72 49·1	+ 1·1	Ditto.
Loch Inver	58 10	5 12	72 36·9	72 33·1	+ 3·8	Ditto.
Durness............	58 34	4 44	72 51·3	72 43·1	+ 8·2	Ditto, associated with primary limestone.
Thurso	58 35	3 32	72 34·0	72 37·0	− 3·0	Old Red sandstone.
‡Stromness.........	58 57	3 16	72 46·8	72 47·1	− 0·3	Ditto.
‡Lerwick............	60 09	1 08	73 13·2	73 14·1	− 0·9	Ditto.
‡Kirkwall	58 59	2 58	72 42·2	72 46·6	− 4·4	Ditto.
Wick	58 25	3 05	72 40·8	72 29·2	+11·6	Ditto.
Golspie	57 58	3 58	72 26·3	72 19·9	+ 6·4	Oolite and Old Red sandstone.
Dingwall	57 34	4 25	72 25·8	72 09·7	+16·1	Old Red sandstone.

‡ Obtained through the kindness of Colonel James.
* Obtained through the kindness of Mr. Stanford, Charing Cross.

Let us now divide the stations according to their geological character into two groups, the first group comprising the unstratified rocks, trap, and granite; and the second every other formation. We shall find that there are thirteen stations, including Tobermorie, in the former, and forty-one stations in the latter group.

The sum of the squares of the differences between the observed and calculated dip for the thirteen stations is 4394′·2, and, consequently, the mean probable error is 12′·9.

If we exclude Tobermorie, these numbers are 1053′·4, 6′·6. For the group of forty-one stations we have the sum of squares=2486′·1, and the mean probable error=5′·3.

We thus see that, whether we include Tobermorie or leave it out, the mean probable error of dip for those stations in the neighbourhood of igneous rocks is greater than for those where the formations are of a stratified description.

DIVISION II.—*Total Force.*

These observations were taken by two different methods.

1. *Method of deflections and vibrations.*—The instruments here used, and the method of observation, are already so well known, that it is unnecessary to describe them. Full details regarding these will be found in the Admiralty Manual of Scientific Inquiry, 3rd edit., 1859. By means of deflections, $\frac{m}{X}$, or the ratio between the magnetic moment of the magnet used and the earth's horizontal force at any station, is obtained, and by means of vibrations we obtain mX or the product of the same quantities. Having

thus obtained both $\frac{m}{X}$ and m X, either of the quantities m, X may now be found.

The earth's horizontal force for any station being thus found, we have only to divide it by the cosine of the *observed* dip at the station taken at the same time, in order to find the total magnetic force.

The following observations with the instrument used in the survey were made at Kew as a base station.

Table VII.

Total Magnetic Force obtained by the Survey Unifilar.

Date of observation, 1857.	Total force.
Aug. 5	10·291
,, ,,	10·297
Oct. 14	10·292
,, 15	10·301
1858.	
June 21	10·281
,, ,,	10·291
,, ,,	10·300
,, ,,	10·304
Mean	10·295

We may without error regard this mean result as the value in British units of the total magnetic force given by the instrument used in the survey at Kew Observatory, and corresponding to the epoch 1st January, 1858. The following series of observations made by another equally reliable instrument, also at Kew, affords perhaps a still more reliable determination.

Table VIII.

Total Magnetic Force obtained by the Kew Unifilar.

Date of observation, 1857.	Total force, monthly means.
April	10·3025
May	10·3080
June	10·300
July	10·306
August	10·287
September	10·306
October	10·315
1858.	
January	10·282
February	10·299
March	10·296
April	10·291
May	10·3075
June	10·280
July	10·296
August	10·302
September	10·2875
October	10·317
November	10·301
Total force, January 1858, most probable value	10·299

It will be seen how nearly this value coincides with that given by the Scotch survey instrument.

No correction of any kind has been applied to the observed values of total force at the different stations.

At some of the stations vibrations only were taken. In such cases, it is necessary to know the moment of the magnet at the time of observation, in order to eliminate it from the product $m\,X$. This may easily be found; for every complete observation gives us a value of m, as well as of X.

These values of m will be found to vary with the time, because the magnet is gradually losing magnetism, and in consequence its moment is slowly diminishing. If, therefore, we combine these values together, each year separately, by the method of least squares, we shall be enabled to express the magnetic moment in terms of the time. We have used this method to find the value of X in those cases in which vibrations alone were taken; but for those in which both vibrations and deflections were observed, X has been determined by means of the two equations thereby furnished.

In the following Table are exhibited the values of X obtained by both these methods, and also the value of the total force for the different stations obtained from the observed values of horizontal force and dip, by means of the formula—

$$\text{Total force} = \frac{\text{horizontal force}}{\text{cosine dip}}.$$

TABLE IX.

Station.	Date.	mX.	Greenwich mean time of observation.	$\frac{m}{X}$.	Greenwich mean time of observation.	Calculated value of m.	X.	Total force.
	1857.		h m		h m			
Makerstoun	Aug. 10	1·7248	....	·14391	....	....	3·4620	10·548
Gretna	15	1·7225	1 0 P.M.	·14382	2 4 P.M.	....	3·4604	10·505
	15	....	....	·14389	2 4			
Dumfries	17	1·7280	1 22	......	....	·49777	3·4714	10·519
Newton Stewart ..	19	1·7138	11 55 A.M.	·14464	0 44	....	3·4424	10·523
	19	....	....	·14460	0 44			
Stranraer	20	1·7110	11 0	......	....	·49767	3·4381	10·519
Ayr	22	1·7000	0 4 P.M.	·14561	0 59	....	3·4171	10·548
Lamlash	25	1·7061	6 11	·14493	7 5	....	3·4310	10·595
Helensburgh......	28	1·6662	1 40	·14846	0 35	....	3·3500	10·538
Lochgoilhead ...	29	1·6805	5 30	......	....	·49735	3·3789	10·531
Ardrishaig.........	Sept. 4	1·6740	4 17	·14761	3 27	....	3·3677	10·575
Oban	7	1·6653	11 28 A.M.	·14829	10 35 A.M.	....	3·3511	10·560
Corpach	8	1·6541	2 25 P.M.	·14946	1 41 P.M.	....	3·3267	10·702
Fort Augustus ...	9	1·6312	3 4	......	....	·49697	3·2822	10·647
Inverness	11	1·6255	1 17	·15171	2 40	....	3·2733	10·667
Banff...............	15	1·6319	4 6	·15126	5 10	....	3·2846	10·596
Peterhead	17	1·6320	1 4	......	....	·49669	3·2856	10·582
	17	1·6318	1 33					
Aberdeen	19	1·6329	0 24	·15093	11 35 A.M.	....	3·2891	10·543
Kintore	21	1·6520	1 16	·14919	0 18 P.M.	....	3·3276	10·550
Alford	22	1·6440	10 20 A.M.	·14943	2 35	....	3·3168	10·599
Braemar	24	1·6657	2 20 P.M.	......	....	·49644	3·3553	10·587
Pitlochry	28	1·6521	11 19 A.M.	·14924	10 34 A.M.	....	3·3272	10·535
Dalwhinnie	29	1·6550	0 28 P.M.	......	....	·49626	3·3349	10·598
Larbert	Oct. 1	1·6565	3 52	·14869	3 9 P.M.	....	3·3378	10·552
Edinburgh	5	1·6853	0 31	......	....	·49606	3·3974	10·536

TABLE IX. (*continued.*)

Station.	Date.	mX.	Greenwich mean time of observation.	$\frac{m}{X}$.	Greenwich mean time of observation.	Calculated value of m.	X.	Total force.
	1858.		h m		h m			
Makerstoun	July 7	....	....	·14080	11 56 A.M.	·48750	3·4626	10·545
	7	....	....	·14079	0 42 P.M.			
Edinburgh	9	1·6624	3 43 P.M.	....	....	·48748	3·4101	10·586
	10	1·6573	11 51 A.M.	·14346	0 41	....	3·3988	10·551
Ardrossan	12	1·6663	3 38 P.M.	·14260	1 50	....	3·4184	10·621
Port Askeg	17	1·6718	1 18	·14216	0 12	....	3·4293	10·655
Bridgend	19	1·6722	4 32	·14199	2 41	....	3·4317	10·675
Tobermorie	24	1·5374	5 17	·15436	6 17	....	3·1560	10·661
Glenmorven	26	1·6382	3 14	....	....	·48733	3·3616	10·899
Balmacarra	28	1·5838	0 49	·15005	2 35	....	3·2489	10·634
Kyleakin	29	1·5862	7 10	....	....	·48730	3·2551	10·636
Broadford	31	1·5854	11 30 A.M.	·14979	10 3 A.M.	....	3·2546	10·682
	31	....	....	·14956	10 35			
Portree	Aug. 3	1·5951	6 41 P.M.	....	....	·48726	3·2737	10·605
Stornoway.........	6	1·5604	9 59 A.M.	·15201	10 58	....	3·2039	10·689
	6	1·5655	2 31 P.M.	·15207	11 31	....	3·2085	
Callinish	9	1·5566	2 2	....	....	·48720	3·1949	10·666
Cross	11	1·5459	1 21	·15354	2 53 P.M.	....	3·1730	10·742
	11	....	....	·15355	3 17			
Loch Inver	16	1·5357	1 10	......	....	·48714	3·1446	10·512
	16	1·5260	1 57					
	16	1·5339	5 2					
Durness............	19	1·5380	10 23 A.M.	....	....	·48711	3·1574	10·697
Thurso	23	1·5594	2 9 P.M.	....	....	·48707	3·2017	10·674
Lerwick............	30	1·5103	1 17	·15675	2 21	....	3·1041	10·738
Kirkwall	Sept. 1	1·5475	11 19 A.M.	·15288	0 18	....	3·1815	10·721
	1	1·5572	2 10 P.M.	·15266	1 13	....	3·1937	
	1	1·5582	2 56	....	....	·48699	3·1996	
Wick	4	1·5531	1 53	....	....	·48696	3·1894	10·700
Golspie	7	1·5727	3 3	....	....	·48693	3·2299	10·692
Dingwall	9	1·5647	1 57	....	....	·48691	3·2134	10·632

It may be observed, in passing, that the moments in the above table show us that the loss of magnetism of the needle was much more rapid during the first year than the second; the reason being, that the needle had been magnetized about the beginning of 1857, and was therefore during the first year's observations a comparatively new magnet.

It is now necessary to combine our total forces by the method of least squares. If we exclude Loch Inver and Glenmorven, both of which seem to be much affected by local disturbance, we obtain f, or the total force at the central station, lat. 56° 55′ N., long. 4° 21′ W.=10·614; u, or the angle which the isodynamic lines make with the meridian=−52° 45′, or their direction is from N. 52° 45′ E. to S. 52° 45′ W.; and r, or the rate of increase of total force in a normal direction=·000961 (British units) for each geographical mile.

It will be remembered that the unifilar used in the Scotch survey gave the total force at Kew=10·295.

Let us suppose that this number represents with sufficient accuracy the total force in London, which is only a few miles from Kew, on 1st Jan. 1858.

Making this our unit, we obtain the following values of f and r for the central station, $f = 1\cdot0309$; $r = \cdot0000933$.

We may now compare together the two surveys, with respect to u and r, in the following Table;—

TABLE X.

Central Station.		Epoch.	u.	r.
Lat.	Long.			
56° 40′ N.	3° 30′ W.	1 Jan. 1837	−50° 02′	·0001320
56 55 N.	4 41 W.	1 Jan. 1858	−52 45	·0000933

From this Table, it would seem that the angle u has changed very little during the twenty-one years between the two surveys; while, on the other hand, r, or the change of force in the normal direction for one geographical mile, appears to have diminished considerably.

In the following Table the observed values of total force are compared with those calculated for the various stations:—

TABLE XI.

Station.	Observed Total Force.	Calculated Total Force.	Observed minus calculated.
Makerstoun	10·546	10·517	+·029
Edinburgh	10·558	10·548	+·010
Gretna	10·505	10·501	+·004
Dumfries	10·519	10·515	+·004
Newton Stewart	10·523	10·525	−·002
Stranraer	10·519	10·535	−·016
Ayr	10·548	10·553	−·005
Lamlash	10·595	10·564	+·031
Helensburgh	10·538	10·581	−·043
Lochgoilhead	10·531	10·590	−·059
Ardrishaig	10·575	10·594	−·019
Oban	10·560	10·614	−·054
Corpach	10·702	10·626	+·076
Fort Augustus	10·647	10·631	+·016
Inverness	10·667	10·636	+·031
Banff	10·596	10·614	−·018
Peterhead	10·582	10·594	−·012
Aberdeen	10·543	10·582	−·039
Kintore	10·550	10·592	−·042
Alford	10·599	10·598	+·001
Braemar	10·587	10·601	−·014
Pitlochry	10·535	10·592	−·057
Dalwhinnie	10·598	10·614	−·016
Larbert	10·552	10·563	−·011
Ardrossan	10·621	10·564	+·057
Port Askeg	10·655	10·601	+·054
Bridgend	10·675	10·600	+·075
Tobermorie	10·661	10·634	+·027
Glenmorven	10·899	10·632	+·267

TABLE XI. (*continued.*)

Station.	Observed Total Force.	Calculated Total Force.	Observed minus calculated.
Balmacarra	10·634	10·655	−·021
Kyleakin	10·636	10·656	−·020
Broadford	10·682	10·658	+·024
Portree	10·605	10·673	−·068
Stornoway	10·689	10·713	−·024
Callinish	10·666	10·715	−·049
Cross	10·742	10·721	+·021
Loch Inver	10·512	10·687	−·175
Durness	10·697	10·697	·000
Thurso	10·674	10·676	−·002
Lerwick	10·738	10·707	+·031
Kirkwall	10·721	10·684	+·037
Wick	10·700	10·660	+·040
Golspie	10·692	10·655	+·037
Dingwall	10·632	10·645	−·013

If we divide the stations as before into two groups, the first comprising trap and granite, and the second every other formation, we shall find that there are twelve stations, including Glenmorven, in the former, and thirty-one stations, including Loch Inver, in the latter class.

The sum of the squares of the differences between the observed and calculated force for the twelve stations is =·0915 (British units), and, consequently, the mean probable error is ·061.

If we exclude Glenmorven, these numbers are ·0202, ·030.

For the group of thirty-one stations we have—

Sum of squares=·0577 ; mean probable error=·030.

If we exclude Loch Inver, these numbers are ·0270, ·020.

We thus see, that whether we include Glenmorven and Loch Inver or leave them out, the mean error of force for those stations in the neighbourhood of igneous rocks is greater than for those where the formations are of a stratified description.

In the second map attached to this Report (Plate 7), the isodynamic lines for 1st January, 1837, are compared with those for 1st January, 1858 ; the force at London being reckoned=unity in both cases. It will be noticed, however, that we have no record of the absolute change that has taken place in the total force between the two epochs, as we have no absolute measure of the force at London for 1st January, 1837.

2. *Dr. Lloyd's Statical Method.* — In this method the dip circle is employed. A needle is loaded with a small weight, and its position of equilibrium enables us to find the product of its magnetic moment into the earth's magnetic force. The needle is then removed and attached to an arm at right angles to that which carries the microscopes, it being now used to deflect another needle substituted in its former place.

The moveable arm is next turned round until the deflected needle assumes a position at right angles to the deflecting needle, so that the extremities of the former are viewed by the microscopes. The position of the deflected needle enables us to find the ratio between the magnetic moment of the deflecting needle and the earth's magnetic force. A detailed description of his instrument is given by the Rev. H. Lloyd in the Transactions of the Royal Irish Academy for 1858.

In determining the total force by this method, a constant is made use of, which is best found at the base station by comparison with a unifilar. *A priori,* there is no reason for supposing that this constant will change, so that it only requires to be determined once for all; yet, in the instrument used in the Scotch survey, there is reason for supposing that a change in the value of the constant took place between the first year and the second.

This will be seen by the following Table, which exhibits the values of the total magnetic force given by the circle at Kew at different periods, the same constant being used throughout:—

Table XII.

Date.	Total Force. Face of deflected needle to the East.	Total Force. Face of deflected needle to the West.
1857.		
Aug. 6.........	10·310	
7.........	10·309	
Oct. 14.........	10·257	
15.........	10·252	
1858.		
Jan. 16.........	10·274	
18.........	10·269	
June 11.........	....	10·228
14.........	....	10·212
14.........	....	10·230
29.........	....	10·212
29.........	....	10·214
Nov. 8.........	10·293	
30.........	10·288	
Dec. 1.........	10·294	
1.........	10·288	
3.........	10·293	
3.........	10·286	
1859.		
Feb. 2.........	10·314	

From this Table it will be seen, that while the instrument with the face of the deflected needle to the east gave on the 6th of August, 1857, a reading as high as 10·310, on the 15th of October of the same year this had fallen as low as 10·252, from which it gradually rose again, until in February, 1859, it had attained the same value as at first.

The constant seems to have been chosen to make the first two observations of August 6 and 7, 1857, give a value for the total force = 10·310, but from a table already given, its most probable value about this period was found to be 10·299, or nearly 10·300. Let us, therefore, deduct 0·01 from the values of total force obtained by this method during the first year's survey, for in these the same constant and arrangement of instrument were employed, which gave the value 10·31 at Kew. We thus obtain the following table of comparison between the results obtained during the first year by the two methods:—

Table XIII.

Station.	Date.	Total force. (1) By Dr. Lloyd's method.	(2) By the method of vibration.	(2)−(1)
	1857.			
Makerstoun	Aug. 10	10·527	10·548	+·021
Gretna	15	10·475	10·505	+·030
Dumfries	17	10·497	10·519	+·022
Newton Stewart	18	10·530	10·523	−·007
	19	10·531	10·523	−·008
Stranraer	20	10·527	10·519	−·008
Ayr	22	10·529	10·548	+·019
	22	10·525	10·548	+·023
Lamlash	25	*10·571	10·595	+·024
Helensburgh	28	10·551	10·538	−·013
Lochgoilhead	29	10·547	10·531	−·016
Helensburgh	Sept. 3	10·561	10·538	−·023
	3	10·564	10·538	−·026
Ardrishaig	4	10·560	10·575	+·015
Oban	7	10·582	10·560	−·022
Corpach	8	10·685	10·702	+·017
Fort Augustus	9	10·663	10·647	−·016
Inverness	11	10·673	10·668	−·005
Banff	16	10·576	10·596	+·020
Peterhead	17	10·540	10·582	+·042
Aberdeen	19	10·567	10·543	−·024
Kintore	21	10·610	10·550	−·060
Alford	22	10·594	10·599	+·005
Braemar	24	10·564	10·587	+·023
Pitlochry	28	10·551	10·535	−·016
Larbert	Oct. 1	†10·541	10·552	+·011
Edinburgh	5	10·522	10·536	+·014

* Altered the western Y of the lifter before taking this observation. Again at Oban.
† Tightened screws before this observation.

It appears from this Table, that, considering the results obtained by the method of vibrations as standards with which to compare those obtained by Dr. Lloyd's process, the latter are found to differ in several instances considerably from the former, sometimes in a positive and sometimes in a negative direction. Proceeding now to the observations of 1858, I find that these were taken with the face of the deflected needle to the west. They are therefore comparable with the five observations taken at Kew during June 1858. The mean of these five observations gives 10·219 as the value of the total force at Kew. This is ·08 less than the probable value; so that we ought to add this amount to all the observations taken by this process during 1858. We thus obtain, as before, the following table, in which the results of the two methods for 1858 are compared together :—

Table XIV.

Station.	Date.	Total force. (1) By Dr. Lloyd's method.	(2) By the method of vibrations.	(2)−(1)
	1858.			
Ardrossan	July 12	10·614	10·621	+·007
Port Askeg	16	10·714	10·655	−·059
Bridgend	19	10·703	13·675	−·028
Tobermorie	24	10·799	10·661	−·138
Glenmorven	26	10·754	10·899	+·145
Balmacarra	28	10·692	10·634	−·058
Kyleakin	29	10·672	10·636	−·036
Broadford	30	10·693	10·682	−·011
Portree	30	10·636	10·605	−·031
Stornoway..................	Aug. 5	10·727	10·689	−·038
Callinish	10	10·741	10·666	−·075
Cross	11	10·759	10·742	−·017
Loch Inver	16	10·619	10·512	−·107
	16	10·636	10·512	−·124
Durness.....................	18	10·743	10·697	−·046
Thurso	23	10·684	10·674	−·010
Lerwick.....................	30	10·716	10·738	+·022
Kirkwall	31	10·727	10·721	−·006
Wick	Sept. 4	10·720	10·700	−·020
Golspie	7	10·708	10·692	−·016
Dingwall	9	10·696	10·632	−·064

By this Table we see that the constant which suited the observations taken at Kew in June 1858 does not suit those taken in Scotland a month or two afterwards, for, when applied to them, it makes the resulting force too great. The instrument must therefore have changed its constant between June and July in such a manner, that, had it been observed at Kew in July, it would have given a larger reading than it gave in June. This agrees with what we inferred from the observations of Table XII. taken at Kew with the face of the deflected needle to the east, viz. that a rise in the readings must have taken place at some time between January and November 1858. To conclude,—in this case at least, the results obtained by Dr. Lloyd's method do not bear comparison in accuracy with those determined by means of the method of vibrations. I have therefore made no use of the former in deducing general results.

Division III.—*Declination.*

During the first year (1857) the Declination observations were made in the following manner. A collimator magnet was employed, the division on the glass scale of which corresponding to the magnetic axis was first accurately determined. Great care was taken that the collimator scale should not be touched, or its position with reference to the magnet in any way altered*.

* There is every reason to believe that this care was successful in securing a fixed position of the magnetic axis with reference to the scale. From a determination at Kew before the commencement of the first year's survey, 49·7 on the scale denoted the magnetic axis. Be-

An altitude and azimuth instrument by Cary, on a tripod firmly placed, was turned until the division on the glass scale of the magnet corresponding to the magnetic axis coincided with the vertical wire of the telescope, and the azimuth circle was then read. The altitude and azimuth instrument was then turned towards the sun, the time at which his centre crossed the middle wire was found by a chronometer, whose error and rate were known, and the reading of the azimuth circle was noted. The latitude and longitude of the place and the time of observation being supposed to be known, the astronomical azimuth of the sun at the moment of observation is given by a well-known formula. The difference between the readings of the azimuth circle for the sun's centre and the magnetic axis enables us then at once to determine the magnetic declination. The altitude and azimuth instrument was often allowed to remain in position for some hours, during which time occasional readings of the magnetic axis were taken, and at the same time the azimuth of some fixed object was read occasionally, in order to see if the tripod-stand had shifted. The silk thread by which the magnet was suspended was carefully kept as free from torsion as possible, and the amount of torsion was moreover examined and eliminated from time to time. The amounts occasionally found to be present were always of such trifling consequence that no correction on their account has been applied to the observations.

The chronometer used was a pocket instrument by Arnold and Dent, No. 5155. Its rate appears to have been somewhat irregular, owing probably to the motion it received in travelling. At almost every station, however, altitudes of the sun were taken, by which the correct time, and consequently also the error of the instrument, were determined.

For one or two stations no altitudes were taken, and consequently no chronometer error determined. Here the following method was pursued. A correction was applied to the last determined chronometer error, depending upon the time that had elapsed since, and on the most probable chronometer rate. The chronometer error so corrected was used in the azimuth observation of the station whose altitude observation was wanting.

During the years 1858 and 1859 self-recording magnetometers were continuously in operation at Kew Observatory, by means of which the magnetic declination at any moment might be determined. The traces furnished by the declination magnetometer have been reduced at General Sabine's office at Woolwich, and the hourly means of the declination, free from disturbance, for every month of both those years have been determined. This enables us to say with great accuracy what correction ought to be applied to a declination observation taken at Kew at any hour of any month of any year near this date, in order to reduce it to the 31st of December (mean of all the hours) of the same year in which it was taken.

Presuming that these corrections are also applicable to Scotland, and to 1857, they have been used in reducing the observations of declination taken in that year to the epoch of January 1, 1858. In reducing those taken in 1858 a somewhat different method has been pursued. During that year the Kew magnetometers, as already mentioned, were in operation. Suppose that we take the mean of all the hours of January 1858, freed from disturbance, as

fore the second year's survey its position had changed to 49·0 (an inconsiderable difference). At Thurso, on August 23, 1858, the magnet was observed erect and inverted, and 49·0 was still found to denote the axis. At Lerwick, the next station after Thurso, the glass scale was wiped, after which the axis appears to have changed; but, as in every observation afterwards the magnet was viewed both erect and inverted, this shifting of the axis was of little consequence.

representing approximately the declination at the epoch of January 1, 1858. It will not do so exactly, because it will correspond to the middle and not to the beginning of January; but the difference will be so trifling, that we may suppose the correspondence to be exact without further refinement.

Now, by means of the traces of the magnetograph we can find the difference between the declination at Kew at any moment of 1858 and that corresponding to the epoch of January 1, 1858, as above defined. And this we can do even if a considerable magnetic disturbance be going on at the moment we fix upon for comparison with the epoch, because this disturbance is registered by the magnetograph, and it may therefore be measured and allowed for.

Now, the moment at which the needle was observed at any station in Scotland in the year 1858 has been recorded; if, therefore, we suppose the same magnetic changes to take place simultaneously in Scotland and at Kew, the indications of the Kew magnetograph will afford us the means of reducing accurately the observations of declination taken in Scotland in 1858 to our epoch January 1, 1858. This method has been pursued with these observations.

The following Table exhibits the most probable value of the absolute declination at Kew corresponding to 1st January, 1858, the method of reduction to epoch being that now mentioned:—

Table XV.

Date.	Time of Observation.	Needle used.	Declination. Observed.	Declination. Reduced to epoch 1 Jan. 1858.
1858.	h m			
Jan. 5	10 5 A.M.	Survey	21° 57′·5	21° 56′·5
5	2 10 P.M.	"	22 3·0	
Feb. 4	4 13 "	"	21 58·6	21 54·8
5	10 31 A.M.	"	21 54·4	
23	1 15 P.M.	"	21 59·8	
Mar. 1	11 22 A.M.	"	22 2·3	21 56·0
2	2 24 P.M.	"	22 8·0	
4	10 34 A.M.	"	21 56·2	
5	2 6 P.M.	"	22 3·3	
April 26	1 7 "	"	22 3·0	21 57·0
29	11 46 A.M.	"	21 59·5	
May 26	0 4 P.M.	"	22 0·2	21 56·6
26	4 15 "	"	21 59·8	
Aug. 13	3 9 "	Kew	21 59·1	21 55·6
Sept. 16	3 21 "	"	21 54·7	21 57·1
Oct. 14	3 32 "	"	21 54·3	21 55·1
1859.				
Sept. 27	4 43 "	"	21 44·3	21 53·4
Oct. 31	11 28 A.M.	"	21 48·6	21 57·1
Nov. 18	4 7 P.M.	"	21 46·4	21 56·6
19	0 29 "	"	21 48·0	
Dec. 21	3 17 "	"	21 45·8	21 54·9
			Mean declination, Jan. 1, 1858	21 55·9

The following Table exhibits the declinations taken during the first year's survey, reduced to the epoch by the method already mentioned :—

TABLE XVI.

DECLINATIONS—1857.

Station.	Date.	Greenwich mean time of observation.	Declination. Observed.	Declination. Reduced to epoch 1 Jan. 1858.
	1857.	h m	° ′	° ′
Makerstoun	Aug. 10	7 54 A.M.	23 52·5	23 56·1
Melrose	12	5 44 P.M.	24 28·0	24 27·4
Edinburgh	13	4 12 „	24 59·2	24 55·1
	13	1 12 „	25 4·5	24 56·0
Gretna	15	1 23 P.M.	23 41·2	23 32·7
Dumfries	17	9 8 A.M.	24 46·3	24 48·2
	17	10 20 „	24 48·7	24 46·4
	17	1 23 P.M.	24 55·0	24 46·5
Newton Stewart	18	5 29 „	25 11·5	25 10·4
Stranraer	20	9 48 A.M.	25 37·2	25 37·2
	20	10 18 „	25 40·2	25 38·0
	20	1 18 P.M.	25 48·2	25 39·7
Ayr	22	9 9 A.M.	25 24·7	25 26·6
	22	10 9 „	25 24·7	25 23·9
Glasgow	24	9 31 „	25 28·3	25 28·8
	24	10 30 „	25 30·2	25 27·3
	24	2 31 P.M.	25 34·7	25 27·5
Brisbane	26	0 16 „	25 21·7	25 14·2
Cumbray	27	1 41 „	25 44·6	25 36·5
Helensburgh	28	11 10 A.M.	25 43·8	25 38·7
	28	3 53 P.M.	25 44·7	25 40·6
Lochgoilhead	29	4 8 „	25 56·2	25 52·1
Campbelton	Sept. 2	7 38 A.M.	26 19·2	26 23·5
Ardrishaig	4	2 45 P.M.	26 34·8	26 29·8
	4	5 14 „	26 30·5	26 29·9
Oban	7	9 42 A.M.	26 11·0	26 11·6
Corpach	8	9 55 „	26 22·3	26 21·9
Fort Augustus	9	6 22 P.M	26 6·0	26 6·0
	9	4 17 „	26 4·3	26 2·3
Inverness	14	9 22 A.M.	25 56·5	25 58·7
Elgin	14	4 32 P.M.	25 8·2	25 6·7
	14	6 48 „	25 6·8	25 7·1
Banff	16	10 16 A.M.	25 18·7	25 17·4
Peterhead	17	4 57 P.M.	24 34·2	24 33·4
Aberdeen	19	1 6 „	24 37·5	24 29·5
	19	4 12 „	24 34·3	24 32·2
Alford	22	3 20 „	24 39·3	24 35·7
	22	3 50 „	24 38·2	24 35·6
Braemar	24	9 27 A.M.	25 7·2	25 8·7
	24	11 0 „	25 12·7	25 8·8
Pitlochry	28	8 0 „	25 18·2	25 23·0
Dalwhinnie	29	7 5 „	25 50·2	25 54·0
	29	7 52 „	25 49·7	25 54·5
Edinburgh	Oct. 5	11 45 A.M.	24 59·2	24 53·6
	5	3 54 P.M.	25 2·8	25 0·2

In 1858 the declination was observed by means of an instrument of a different kind. This was invented by Dr. Lloyd, and it is described by him in the Proceedings of the Royal Irish Academy, January 11, 1858. In this instrument the telescope is horizontal, and there is a mirror by which the sun may be reflected into the telescope, and its azimuth determined. The mirror being adapted to the telescope by which the scale of the magnets is observed, the same horizontal circle is made to serve for determining everything, and thus the theodolite and additional tripod are dispensed with, while the altitudes of the sun are determined by means of a small sextant and artificial horizon. A considerable reduction in the observer's travelling equipment is thus obtained.

In Dr. Lloyd's instrument three adjustments are required.

1. The axis of the mirror must be horizontal. This is tested by a small riding level.

2. The plane of the mirror must be parallel to the axis. Should this not be exactly the case, the error is eliminated by first observing, then reversing the axle in its Ys, observing again, and taking a mean of the two readings.

3. The line of collimation of the telescope must be perpendicular to the axis of the mirror. The error produced by want of a perfect adjustment of this nature may be got rid of by viewing the sun (1°) direct, or facing the south, (2°) backwards, or facing the north.

For, let δ denote the error of azimuth in a direct observation, δ' the same in a back observation; then it may be shown that

$$\delta = \pm C \frac{\sin^2 \frac{1}{2} \text{alt.}}{\cos \text{alt.}},$$

$$\delta' = \mp C \frac{\cos^2 \frac{1}{2} \text{alt.}}{\cos \text{alt.}},$$

where C is a constant quantity.

Hence if A, B denote the readings of the circle in the fore and back observations, we have in the fore observation $\delta = \pm \{180° - (A - B)\} \sin^2 \frac{1}{2} \text{alt.}$, the sign of δ being such that the truth lies between the results given by the two observations.

Before the commencement of the second year's survey, the axis of the mirror had been accurately adjusted so as to be at right angles to the line of collimation of the telescope, but on July 20, at Bridgend, the axis was found to be very much out. A plumb line was suspended, which was viewed by direct vision, and backwards by reflection. When viewed by direct vision, the circle reading was 348° 18′, while by back reflection it was 350° 20′, the angle of inclination of the mirror to the horizon in the back observation being about 80°; the formula $122' = C \frac{\cos^2 10°}{\cos 20°}$ gives $C = 118'$,—a large amount. In consequence of this, it has been thought advisable to reject all the observations before Bridgend. At Bridgend the mirror was readjusted, and for all the observations afterwards, with the exception of two, the sun was observed both by direct and by back reflection. The following Table exhibits the values of δ and C at the various stations, where both fore and back observations were taken :—

Table XVII.

Station.	δ	C
Glenmorven	$+14'\cdot3$	$44'\cdot8$
Balmacarra	$+2\cdot9$	$35\cdot8$
Kyleakin	$+3\cdot1$	$41\cdot3$
Stornoway	$+2\cdot2$	$46\cdot0$
	$+1\cdot3$	$35\cdot4$
Callinish	$+1\cdot2$	$41\cdot2$
Cross	$+2\cdot5$	$39\cdot9$
Loch Inver	$+4\cdot3$	$47\cdot2$
Durness	$+2\cdot7$	$40\cdot1$
Thurso	$+3\cdot2$	$35\cdot3$
Lerwick	$+1\cdot0$	$41\cdot2$
Wick	$+4\cdot0$	$43\cdot0$
	$+2\cdot0$	$36\cdot9$
Golspie	$+1\cdot3$	$37\cdot5$

We see from this Table that though C (which is equal to twice the angle by which the mirror is out in adjustment), as exhibited in the third column, is somewhat large, yet the correction to be applied to the actual observations, denoted by δ, is generally very small, the only exception being Glenmorven, where the altitude of the sun was high at the time of the azimuth observation.

It has been mentioned that there were two stations after Bridgend at which no back observations were taken. One of these was Port Ellen, the next station after Bridgend, but as the altitude of the sun was high when the azimuth observation was taken there, it has not been thought advisable to apply a correction proceeding upon an assumed value of C. The other station was Kirkwall, which occurs in point of time between Lerwick and Wick. The value of C for Lerwick is $41'\cdot2$, and for Wick it is $43'\cdot0$. If we assume the mean of these, or $42'\cdot1$ as the value for Kirkwall, we find $\delta=+2'\cdot2$, which value has accordingly been adopted.

Table XVIII. (p. 189) exhibits the declinations for 1858, corrected for error of mirror, and reduced to 1st January, 1858.

If we now take all the declinations, with the exception of that for Glenmorven, which seems to be influenced by local attraction, we obtain by the method of least squares u, or the angle which the isogonic lines make with the meridian $=-20°\ 58'\cdot3$, or their direction is from N. $20°\ 58'\cdot3$ E. to S. $20°\ 58'\cdot3$ W.; r, or the increase of the declination in a direction perpendicular to the isogonic lines, $=1'\cdot465$ for each geographical mile; and d, or the declination at the central station, lat. $56°\ 54'$ N., long. $4°\ 14'$ W. $=25°\ 53'\cdot6$. The isogonic lines are exhibited in a map (Plate 7) appended to this report.

In Table XIX. (page 190) the observed and calculated declinations are compared together.

If we now divide the stations, as before, into two groups, the first comprising trap and granite, and the second every other formation, we shall find the mean probable error for the former group $=24'\cdot8$, and that for the latter $=11'\cdot1$.

If we examine Tables VI., XI., XIX., in which the difference between the observed and calculated magnetic elements is given for the different stations arranged in the order of observation, we shall, I think, perceive that stations similarly affected with regard to sign are in many cases grouped together. But, from the principle of arrangement adopted, the members of any such group denote stations at which the observations were consecutive with respect to time; so that such stations cannot be very far apart with respect to geographical position.

TABLE XVIII.

Station.	Date.	Greenwich Mean Time of observation.	Declination. Observed.	Declination. Corrected for error of mirror.	Declination. Reduced to 1 Jan. 1858.
	1858.	h m	° ′	° ′	° ′
Glenmorven	July 26	0 32 P.M.	28 14·6	28 28·9	28 21·4
	26	2 16 "	28 16·0	28 30·3	28 20·8
Balmacarra	28	8 47 A.M.	27 24·2	27 27·1	27 32·8
	28	9 53 "	27 25·2	27 28·1	27 31·4
	28	0 3 P.M.	27 32·9	27 35·8	27 33·4
Kyleakin	29	5 11 "	27 47·4	27 50·5	27 50·7
	29	5 27 "	27 45·6	27 48·7	27 49·6
	29	6 35 "	27 46·5	27 49·6	27 50·9
Stornoway	Aug. 5	5 56 "	27 54·3	27 56·5	27 58·3
	5	6 11 "	27 53·0	27 55·2	27 57·2
	5	6 41 "	27 51·0	27 53·2	27 56·1
	6	6 0 "	27 42·6	27 43·9	27 46·7
	6	6 17 "	27 53·2	27 54·5	28 1·1
	6	6 22 "	27 50·2	27 51·5	27 57·2
Callinish	9	2 48 "	28 13·7	28 14·9	28 12·5
	9	3 28 "	28 10·2	28 11·4	28 10·1
	9	3 30 "	28 10·2	28 11·4	28 10·1
	9	5 29 "	28 1·9	28 3·1	28 7·1
	9	5 35 "	28 1·9	28 3·1	28 7·1
	9	6 2 "	28 2·7	28 3·9	28 7·4
	9	6 32 "	28 2·7	28 3·9	28 6·8
Cross	11	9 11 A.M.	28 16·3	28 18·8	28 24·5
	11	10 26 "	28 23·3	28 25·8	28 26·7
	11	11 30 "	28 25·0	28 27·5	28 25·3
	11	0 9 P.M.	28 26·6	28 29·1	28 25·1
Loch Inver	16	9 54 A.M.	27 2·8	27 7·1	27 9·9
	16	10 11 "	27 4·8	27 9·1	27 11·1
	16	11 21 "	27 9·8	27 14·1	27 11·7
	16	11 54 "	27 11·8	27 16·1	27 11·9
	16	0 21 P.M.	27 12·8	27 17·1	27 11·6
Durness	18	3 4 "	27 29·0	27 31·7	27 29·7
	18	4 6 "	27 27·3	27 30·0	27 29·6
	18	4 33 "	27 26·7	27 29·4	27 29·6
	18	5 1 "	27 25·3	27 28·0	27 29·6
Thurso	23	9 41 A.M.	26 21·6	26 24·8	26 27·4
	23	9 51 "	26 22·3	26 25·5	26 26·8
	23	0 45 P.M.	26 35·2	26 38·4	26 33·8
	23	0 52 "	26 34·6	26 37·8	26 33·2
Lerwick	30	8 12 A.M.	25 3·8	25 4·8	25 14·0
	30	8 30 "	25 5·8	25 6·8	25 15·1
	30	10 2 "	25 13·1	25 14·1	25 18·6
	30	10 57 "	25 14·3	25 15·3	25 17·8
	30	11 27 "	25 17·6	25 18·6	25 20·2
	30	0 31 P.M.	25 18·1	25 19·1	25 19·1
Kirkwall	31	5 27 "	26 13·8	26 16·0	26 17·3
	31	5 57 "	26 14·2	26 16·4	26 17·6
Wick	Sept. 4	10 19 A.M.	25 53·4	25 57·4	26 0·0
	4	11 41 "	26 0·9	26 4·9	26 4·1
	4	0 45 P.M.	26 5·4	26 9·4	26 8·4
	4	3 56 "	25 58·6	26 0·6	26 3·4
	4	4 43 "	25 57·2	25 59·2	26 2·4
Golspie	7	4 33 "	26 15·6	26 16·9	26 18·8
	7	4 50 "	26 15·6	26 16·9	26 19·5
	7	5 40 "	26 6·6	26 7·9	26 10·7
	7	6 1 "	26 6·3	26 7·6	26 10·4

Such groups of stations will in fact represent districts, some of them of considerable extent, which thus appear to be similarly affected by local attraction.

The observations are probably insufficient to enable us to determine the disposition of this attractive matter; but there is one very marked case to which I may be permitted to refer.

If we examine Tables VI. and XI. we shall find that the stations in the Island of Isla have their dip diminished and their total force increased by local attraction. On the other hand, the Mull stations have both dip and total force increased, while those in Skye have their dip increased and their total force diminished.

Such a state of things might be brought about by a powerful source of attraction for the north pole of the needle situated a little to the south of the Mull stations at a considerable depth below the surface. This supposition derives confirmation from the fact that the errors due to local attraction are exceedingly large in Mull.

TABLE XIX.

Station.	Observed.	Calculated.	Observed minus calculated.
Makerstoun	23° 56′·1	23° 52′·9	+03′·2
Melrose	24 27·4	24 02·4	+25·0
Edinburgh	24 56·2	24 36·4	+19·8
Gretna	23 32·7	23 58·3	−25·6
Dumfries	24 47·0	24 26·4	+20·6
Newton Stewart	25 10·4	25 02·7	+07·7
Stranraer	25 38·3	25 27·7	+10·6
Ayr	25 25·2	25 26·3	−01·1
Glasgow	25 27·9	25 22·5	+05·4
Brisbane	25 14·2	25 48·3	−34·1
Cumbray	25 36·5	25 47·8	−11·3
Helensburgh	25 39·6	25 48·3	−08·7
Lochgoilhead	25 52·1	26 00·7	−08·6
Campbeltown	26 23·5	26 14·0	+09·5
Ardrishaig	26 29·8	26 22·0	+07·8
Oban	26 11·6	26 34·2	−22·6
Corpach	26 21·9	26 33·1	−11·2
Fort Augustus	26 4·1	26 20·7	−16·6
Inverness	25 58·7	26 08·8	−10·1
Elgin	25 6·9	25 37·6	−30·7
Banff	25 17·4	25 02·0	+15·4
Peterhead	24 33·4	24 25·0	+ 8·4
Aberdeen	24 30·8	24 25·7	+05·1
Alford	24 35·7	24 58·5	−22·8
Braemar	25 8·7	25 20·4	−11·7
Pitlochry	25 23·0	25 24·1	−01·1
Dalwhinnie	25 54·2	25 57·4	−03·2
Glenmorven	28 21·1	27 03·2	+77·9
Balmacarra	27 32·5	27 08·6	+23·9
Kyleakin	27 50·4	27 12·2	+38·2
Stornoway	27 56·1	28 09·1	−13·0
Callinish	28 8·7	28 21·6	−12·9
Cross	28 25·4	28 12·3	+13·1
Loch Inver	27 11·2	27 15·9	−04·7
Durness	27 29·6	27 8·0	+21·6
Thurso	26 30·3	26 16·5	+13·8
Lerwick	25 17·5	25 30·1	−12·6
Kirkwall	26 17·4	26 05·9	+11·5
Wick	26 3·7	25 52·1	+11·6
Golspie	26 14·8	26 16·3	−01·5

The Patent Laws.—Report of Committee on the Patent Laws. Presented by W. Fairbairn, *F.R.S.*

At the meeting of the British Association at Leeds for the year 1858, a Committee was re-appointed for the purpose of taking such steps as might be necessary to render the Patent System of this country, and the funds derived from inventors, more efficient and available for the reward of the meritorious inventors and the advancement of science.

Circumstances beyond control have prevented that Committee from taking any decisive steps in furtherance of the important objects entrusted to them; but those objects have not been lost sight of. No reply has been received from the Commissioners of Patents, either to the Memorial of the Glasgow Committee of the British Association, or of the Public Meeting in Manchester; but some of the questions referred to in those Memorials are adverted to in the Report of the Commissioners just issued. From that Report, it appears that the number of applications for patents may be estimated at about 3000 per annum; that of these 3000 applications not more than about 2000 proceed to the final stage of a patent; and that of the 2000 patents granted, not more than 550 are kept alive beyond three years by the first periodical payment of £50 before the expiration of that term; and the Commissioners anticipate that the fee of £100 payable at the end of the seventh year will not be paid on more than 100 of the surviving 550 patents. Should this anticipation prove correct, the payment by inventors in fees upon patents not surviving beyond one half their term of fourteen years will not be less than at the rate of £100,000 per annum as a direct tax on the inventive genius of the country, in addition to and exclusive of time, labour, and other charges and expenses.

The total outlay in respect of those patents may be estimated as at least £250,000, or a quarter of a million, per annum. The great work of printing and publishing *in extenso* the specifications of patents granted under the old law, that is, from 1711 to the 1st of Oct. 1852, in number 12,977, is completed; and the surplus funds hitherto absorbed by this object will be henceforth available for other purposes.

That surplus is estimated by the Commissioners at £30,000 for the current year 1858-59, and to increase in each succeeding year at the rate of £20,000 per annum. This surplus, after providing for the current expenses, is proposed by the Commissioners to be appropriated to the following objects:—

1. The erection of a Museum for the preservation and exhibition of models, of which a considerable collection already exists at Kensington.
2. The erection of suitable offices for the Commissioners, including a free library of consultation upon a more extended scale than already formed by Mr. Woodcroft.

These most desirable and legitimate objects of application of the "Inventors' Fee Fund" cannot, however, be attained without the sanction of the Lords Commissioners of Her Majesty's Treasury, and a vote of Parliament, inasmuch as all the fees levied on Inventors are by a recent change levied in the shape of stamps, and so pass directly into the Consolidated Fund.

These recommendations of the Commissioners will, it is conceived, be regarded as a most legitimate application of the funds of Inventors, and as one to which the Parliamentary Committee of the British Association will give their aid; but your Committee think that other considerations and other claims upon the Inventors' Fee Fund, and upon the annual surplus, whatever its probable amount, should be forthwith urged upon the Commissioners and upon Parliament.

The Report of the Patent Committee of the British Association to the Leeds Meeting called prominent attention to the two following questions:—

1st. Whether the present scale of payments should be maintained, or reduced, so as to leave no greater surplus than necessary for official expenses?

2nd. If the present scale of payment be maintained, how shall the surplus be appropriated?

The Commissioners of Patents are in favour of maintaining the present scale of payments, on the ground "that any material reduction in the amount of fees would undoubtedly tend to increase the number of useless and speculative patents, in many cases taken merely for advertising purposes."

Your Committee are not insensible to the force of this observation; but they beg respectfully to doubt whether this money check has any effective operation on the class of cases most requiring to be controlled, and whether the remedy is not worse than the disease, in laying an unjustifiable burden on the inventive genius of the country, and effecting a confiscation of property of its own creation.

Your Committee are much struck with the fact, that the application for about 1000 patents is not prosecuted to completion, and in many cases probably not beyond the first stage; that the first periodical payment of £50 at the end of the third year is not made in respect of nearly 1500 of the 2000 patents granted; and that the Commissioners anticipate during the ensuing year the surrender or lapsing of no less than 450 out of the 550 patents which survived the first periodical payment.

It must be borne in mind that the granting of patents in this country is practically without control, no attempt having been made to interpose any of the checks urged before the Committee of the House of Lords in the Session of 1851, and provided for in the three bills of that Session, and in the Act of the subsequent Session, now the law of the land. The payment of £5 on the first application may be regarded as a registration fee: the applicant makes this payment on lodging the papers, obtaining protection and inchoate rights from the moment of his application. This was one of the cardinal features of the new system of 1852; it has been productive of the greatest benefit to inventors, especially to those of the poorer class, by enabling them to obtain inchoate rights, and to create property for themselves by a simple record of their inventions, without publicity and the obstruction of interested opponents. This power of placing inventions on record is also resorted to in many cases by those who do not wish further to secure or appropriate to themselves property in their ideas and inventions, and which forthwith become public property.

The 1500 lapsed patents must be regarded in a different light: these have cost their authors no less than £37,500 for fees and stamps as a direct taxation on their inventive genius, in addition to and exclusive of other payments of at least an equal amount.

Of these 1500 patents, it is believed that the progress of at least 1000 might be arrested with the *consent* of the applicants, if the inquiry before the law officers were substantial instead of merely nominal. Thus a large useless outlay of capital in money and time would be avoided, talents unprofitably employed would be directed into other channels, and the creation of legal rights would be limited and reduced exactly in proportion as the applications were not proceeded with.

Your Committee conceive that the application of a portion of the funds contributed by inventors would be most properly applied to affording them this species of protection against the unprofitable expenditure of time and money: the attempt is surely worth the trial; it would effectually check the prostitution of the patent system to the illegitimate purposes referred to by the Commissioners.

The reward of the meritorious inventor in cases in which he alone of the public has failed to benefit by the fruits of his genius, and the purchase of patent rights in him of extending their terms, was referred to in the Report of the Patent Committee of the British Association at the Leeds Meeting as a legitimate appropriation of a portion of the surplus.

These objects being satisfied, a very large surplus would remain available for the advancement of science by researches having a direct bearing on the reproductive industry of the country. And if it be thought expedient that more money should be levied on the granting of patents than necessary for the expense of the office, inventors have, it is conceived, an irresistible claim for the expenditure of that surplus upon objects bearing on their interests and the advancement of science.

W. Fairbairn.
Edward Sabine.
Thomas Webster.

Aberdeen, Sept. 16, 1859.

Lunar Influence on the Temperature of the Air.
By J. Park Harrison, *M.A.*

1. The definite form assumed by lunar curves of mean temperature, obtained from the means of tables framed expressly for the purpose, was brought before the notice of the British Association at Leeds in proof that the moon exerts an indirect, yet appreciable influence over the atmosphere of our globe*.

A longer series of observations at Greenwich, extending over the period of 43 years, and embracing 520 consecutive lunations, has since been tabulated; and the means of the different columns formed into another, and what may be termed for distinction's sake, a model curve (Plate II. fig. 1). It presents, in common with those which had been already constructed for shorter periods of time, very marked characteristics.

Upon turning to the Plate it will be perceived that the amount of heat signalized by the shaded portion of the curve (or all that rises above the general mean line) is considerably greater at first quarter than at any other period of the lunation, though it will also be noticed that the temperature immediately following on new moon exceeds it in height, on one day by ·10 of a degree (fig. 1). Upon the average, the first half of this curve, from the 2nd or 3rd day before new moon to the 3rd or 4th day before full moon, *rises as much above the general mean as the remaining half falls below it.* It sinks below the mean line at the period to which attention was originally drawn,

* At Dublin, where attention was directed to but a small portion of the lunation, it was shown that the temperature immediately following on the moon's first quarter was higher than the temperature of the third day before first quarter, both at Greenwich and Dublin, for the series of years subjected to examination.

viz. about the 3rd day before first quarter (or the 4th or 5th day of the moon's age), and at three other noticeable points of the curve; these, as I have already stated, are (1) shortly before and (2) shortly after full moon, and (3) immediately after last quarter.

In the colder half of the lunation the temperature rises at full moon, and shortly before last quarter.

2. It is not, however, only upon an average of a long series of yearly means that the proof of lunar influence depends for its establishment. All the more remarkable deviations from the calculated mean temperatures of the day, for which the past year has been distinguished, have followed the model curve in a more or less significant manner, at the seasons of excessive heat or cold above alluded to. I have elsewhere shown that this was the case in November 1858*, and in January, March, and April in the present year†; and it has since proved to be so in September and October, and thus the greatest amount of heat on the average of 12 lunations in 1859 displays itself according to the rule above indicated in the first half of the curve, the greatest amount of cold in the second half (see fig. 2). The mean of the means of the several columns is 51°·1; the mean of the first 14 columns 51°·9, of the remaining 14 columns 50°·2. The table of mean temperatures from which this curve was formed is appended, in order to afford those who may wish to examine more minutely the nature of the influence exerted in separate lunations, an opportunity of doing so. It will also serve to illustrate the method which was adopted in arranging the observations in the several lunar tables from which the curves have been obtained.

3. The popular belief in a tendency in the weather to "clear up," or the contrary, at certain periods of the moon's age—a notion which my own observations appeared to confirm—joined with a strong impression that these seasons would be found to synchronize more or less closely, according to the time of year, with the periods of greatest cold or heat in the lunation, led to the conclusion that the rise or fall in the curves of temperature must be due to the action of terrestrial radiation, *as a secondary cause*; and that the rise in temperature at other periods of the lunation might also possibly be attributed to the opposite state of the atmosphere when radiation upwards to the sky is stopped, more particularly in winter, by the presence of low or thick masses of cloud. This view has been much strengthened during the past year by results which were obtained from an examination of the bi-horary observations of cloud taken day and night continuously for seven years (1840-47)

* See Phil. Mag. for March 1859.

† Whilst, according to the calculated average, the mean temperature at the end of March and beginning of April ought, in each case, to rise above and fall below the mean of the month, in 1859 this was exactly reversed. A very cold period occurred at the end of March, the mean temperature (on the 31st) being 9°·4 below the average of that day of the month for forty-three years, as determined by Mr. Glaisher. But the 31st of March was also the third day before new moon, and the mean temperature of that day of the lunation *in March* for the same number of years falls below the mean temperature of the lunar curve. So also in April, the mean temperature of the 7th day was 17°·5 in excess of the mean temperature of that day for forty-three years at Greenwich, and the mean temperature of the 15th day was 8°·3 below the average. Here the 7th day of April fell on the day of *maximum* temperature for the lunation in *April* or the first octant, and the 15th day of April was the second day before full moon, which is within the cold period which precedes that phase of the moon. The minimum temperature at the Toronto Observatory also in January 1859, which was −26°·5 on the 10th day, rose on the 13th to 36°·0. At Greenwich a similar rise took place from the 9th (or 3rd day before first quarter) to the 12th (or day of first quarter). On the former day the minimum temperature was 28°·5, on the latter 41°·2, and the mean temperatures 33°·6 and 45°·0. There appeared to be a considerable development of electricity at all the periods of low mean temperature. (From a communication made to the London Meteorological Society, and reported in the 'Athenæum.')

2	3	8nt	3	2	1	☾	1	2	3	8nt
42°·0	44°·2	...	43°·0	41°·2	41°·1	48°·0	41°·4	45°·1	43°·8	41°·2 45·0 }
40·6	46·0	...	46·9	46·6	41·5	42·7	42·0	42·8	45·2	43·3
46·4	42·1	40°·8	44·5	48·4	51·2	49·6	48·8	49·6	47·4	35·3
39·9	42·7	43·5	42·5	42·4	45·6	49·8	52·6	45·2	46·8	...
51·6	54·9	54·0	52·3	49·8	52·2	55·9	58·3	59·6	59·0	58·0
57·3	60·9	60·6	57·3	56·4	64·9	60·7	58·5	61·9	69·0	...
73·2	74·3	70·9	67·7	66·5	68·9	61·5	59·9	62·1	69·2	...
59·4	59·5	60·7	66·6	68·1	69·4	62·6	63·4	66·3	69·1	...
50·8	53·0	...	54·4	54·4	52·6	55·8	53·8	52·6	54·7	...
53·1	56·6	56·1	55·9	55·6	51·0	52·6	50·2	36·8	36·3	...
39·0	38·6	...	33·8	33·8	38·9	39·1	38·7	40·2	35·1	...
33·5	33·5	...	33·5	27·9	27·0	25·1	22·8	23·4	23·9	30·0
49·1	50·5	...	49·9	49·3	50·4	50·3	49·2	48·8	49·9	...

Mean...... 50°·2

y Mean Temperature for 43 years consists of 520 lines of figures.

☾	Interval.	●
h m	d h m	
5 34 P.M.	7 16 35	
5 38 A.M.	7 23 47	
8 45 P.M.	8 4 19	
2 21 P.M.	8 4 49	
9 27 A.M.	8 0 50	
4 45 A.M.	7 17 19	See first column.
10 49 P.M.	7 8 21	
2 31 P.M.	7 0 10	
3 25 A.M.	6 18 18	
1 45 P.M.	6 15 28	
10 13 P.M.	6 15 42	
5 42 A.M.	6 18 50	
1 6 P.M.	7 0 36	
9 15 P.M.	7 8 32	*

Lunar Table of Daily Mean Temperature in 1859, at Greenwich*.

Month	3	2	1	●	1	2	3	8ve	3	2	1	☽	1	2	3	8ve
January	41·1	31·8	33·3	38·1	40·2	34·0	34·9	32·9	33·6	37·1	44·2	45·0	40·1	35·2	35·3	...
February	34·1	39·8	42·6	31·5	37·6	41·7	40·2	...	37·9	39·0	44·2	44·5	44·9	45·8	45·9	...
March	46·9	45·8	51·0	54·8	52·0	49·9	49·8	40·5	38·7	40·8	46·6	53·5	52·2	50·6	44·2	.
April	34·0	37·3	45·6	52·3	56·0	55·6	61·1	...	63·0	52·9	53·3	49·3	47·0	43·1	40·4	...
May	53·7	44·1	45·3	46·7	47·4	48·8	47·1	...	47·8	56·4	52·4	50·3	47·4	52·5	51·0	...
June	60·2	64·3	61·1	60·3	61·8	62·3	65·6	...	65·3	63·5	60·7	62·2	64·6	61·5	58·7	66·8
July	68·5	63·1	[illegible]	61·4	59·6	62·2	66·0		61·9	65·1	69·3	[illegible]	65·5	65·1	68·6	72·3
August	69·2	71·5	71·4	69·3	65·4	67·5	65·7	...	62·2	65·4	63·1	60·7	59·7	68·1	68·2	67·9
September	73·4	65·9	65·4	59·7	62·0	55·5	53·3	...	55·4	57·9	59·4	56·0	57·3	59·1	57·6	61·5
October	58·8	67·4	62·0	59·8	56·2	58·7	56·5		56·2	61·1	59·4	63·9	66·8	60·8	62·7	63·2
November	36·3	33·3	32·1	38·1	42·4	36·7	45·6	42·6	41·7	45·3	51·4	48·3	47·2	48·9	50·3	51·2
December	39·6	40·4	41·8	44·7	39·7	46·6	43·0	40·4	39·7	36·2	36·4	33·4	32·1	35·7	47·9	44·2
Means	51·8	50·6	51·0	51·6	51·8	51·6	52·4		50·5	51·7	53·5	53·1	52·3	52·5	52·8	

Month	3	2	1	○	1	2	3	8ve	3	2	1	☾	1	2	3	8ve
January	38·3	34·7	45·0	50·5	43·4	42·0	44·2	...	43·0	41·2	41·1	48·0	41·4	45·1	43·8	41·2 / 45 }
February	43·0	43·5	50·3	49·6	42·6	40·6	46·0	...	46·9	46·6	41·5	42·7	42·0	42·8	45·2	43·3
March	44·2	48·3	47·6	45·2	43·7	46·4	42·1	40·8	44·5	48·4	51·2	49·6	48·8	49·6	47·4	[illegible]
April	42·2	37·4	37·5	37·5	38·2	39·9	42·7	43·5	42·5	42·4	45·6	49·8	52·6	45·2	46·8	
May	52·0	52·7	52·6	52·8	50·3	51·6	54·9	54·0	52·3	49·8	52·2	55·9	58·3	59·6	59·0	58·0
June	61·0	61·0	56·3	60·8	57·4	57·3	60·9	60·6	57·3	56·4	64·9	60·7	58·5	61·9	69·0	
July	75·7	75·2	66·0	68·4	70·7	73·2	74·3	70·9	67·7	66·5	68·9	61·5	59·9	62·1	69·2	
August	57·5	62·3	66·1	67·1	63·9	59·4	59·5	60·7	66·6	68·1	69·4	62·6	63·4	66·3	69·1	
September	59·6	55·1	54·6	57·6	51·8	50·8	53·0	...	54·4	54·4	52·6	55·8	53·8	52·6	54·7	...
October	58·1	57·6	56·3	53·9	53·6	53·1	56·6	56·1	55·9	55·6	51·0	52·6	50·2	30·8	36·3	
November	51·3	46·1	38·5	37·0	37·5	39·0	39·6		33·8	33·8	38·9	39·1	38·7	40·2	[illegible]	
December	42·3	42·0	35·1	37·0	30·8	33·5	31·5		33·5	27·9	27·0	25·1	22·8	23·4	23·9	31·0
Means	[illegible]	51·6	50·8	51·5	48·8	49·1	50·5		49·9	49·3	50·4	50·3	49·2	46·8	49·9	

Mean...... 51°·9 × Mean ..... 50°·2

Note.—The several months commence from the dark lines or stops.

* The Table of Daily Mean Temperature for 43 years consists of 520 lines of figures.

Table of Moon's Phases in 1859.

Months	●	Interval.	☽	Interval.	○	Interval.	☾	Interval.	●
	d h m	d h m	d h m	d h m	d h m	d h m	d h m	d h m	
1858 November	5 4 48 P.M.	8 3 54	13 8 42 P.M.	7 5 42	21 2 24 A.M.	6 15 10	27 5 34 P.M.	7 16 35	
December	5 10 9 A.M.	8 5 19	13 3 28 P.M.	6 21 38	20 1 6 P.M.	6 16 32	27 5 38 A.M.	7 23 47	
1859 January	4 5 25 A.M.	8 1 57	12 7 22 A.M.	6 16 26	18 11 48 P.M.	6 20 57	25 8 45 P.M.	8 4 19	
February	3 1 4 A.M.	7 16 35	10 7 39 P.M.	6 15 2	17 10 41 A.M.	7 3 40	24 2 21 P.M.	8 4 49	
March	4 7 10 P.M.	7 9 29	12 4 39 A.M.	6 17 6	18 9 45 P.M.	7 11 42	26 9 27 A.M.	8 0 50	
April	3 10 17 A.M.	7 1 3	10 11 20 A.M.	6 21 45	17 9 5 A.M.	7 19 40	25 4 45 A.M.	7 17 19	
May	2 10 4 P.M.	6 18 55	9 4 59 P.M.	7 4 7	16 9 6 P.M.	8 1 43	24 10 49 P.M.	7 8 21	
June	1 7 10 A.M.	6 15 37	7 10 47 P.M.	7 11 30	15 10 17 A.M.	8 4 14	23 2 31 P.M.	7 0 10	See first column.
July	30 2 41 P.M.	6 15 12	7 5 53 A.M.	7 19 0	15 0 53 A.M.	8 2 32	23 3 25 A.M.	6 18 18	
August	29 9 43 P.M.	6 17 38	5 3 21 P.M.	8 1 13	13 4 34 P.M.	7 21 11	21 1 45 P.M.	6 15 28	
September	28 5 13 A.M.	6 22 51	4 4 4 A.M.	8 4 27	12 8 31 A.M.	7 13 42	19 10 13 P.M.	6 15 42	
October	26 1 55 P.M.	7 6 36	3 8 31 P.M.	8 3 20	11 11 51 P.M.	7 5 51	19 5 42 A.M.	6 18 50	
November	26 0 32 A.M.	7 15 46	2 4 18 P.M.	7 21 47	10 2 5 P.M.	6 23 1	17 1 6 P.M.	7 0 36	
December	24 1 42 P.M.	8 0 7	2 1 49 P.M.	7 13 23	10 3 12 A.M.	6 18 3	16 9 15 P.M.	7 8 32	*

* New Moon, December 24th, at 5h. 47m. A.M.

at the Royal Observatory at Greenwich, and which were published, amongst other elaborate meteorological tables, in the volumes for those years.

Out of 55 clear days, or what might be considered clear days, there enumerated—those being considered as nearly clear on which the amount of cloud did not exceed ·3—no less than 42 occurred at periods of low mean temperature in the lunation. And it is worth notice, in connexion with this fact, that during the three years (1844, 1845, and 1846), in which the late lamented Radcliffe Observer found from observations taken for the purpose, between the day of first quarter and the day after full moon, "that the moon was visible on an average 137 times on the meridian when the sun is seen only 100 times," the Greenwich Observations of cloud show an unusual number of clear days to have occurred at that station on the three days following on first quarter, the effects of which would appear to be traceable in the curve embracing the years in question (see fig. 4).

Still further to test the point, a curve of the mean amount of cloud in November during the same seven years was formed for the purpose of comparing the approximate amount of cloud on the different days of the moon's age with the line of a lunar curve of mean temperature for 40 consecutive Novembers. It was hardly possible to doubt, on carefully examining the two curves thus placed in juxtaposition,—the waves of cloud being for the most part a day in advance of those of temperature,—that an intimate connexion does exist, as cause and effect, between the amount of cloud at different periods of the lunation and the temperature of the air.

On the Continent, too, it was found that the results obtained by Schübler at Augsburg, from 1813 to 1828, had been examined by M. Arago and admitted to be in accordance with those arrived at by Flaugergues at Viviers, from 1808 to 1828. From a Table of the relative number of serene and clouded days at Augsburg during the above-mentioned sixteen years, M. Schübler found (1) that clear days were more numerous at last quarter; (2) that the greatest number of clouded days occurred towards (*vers*) the second octant. Also in twenty-eight years at three different stations, namely at Munich from 1781 to 1788, at Stuttgard from 1809 to 1812, and at Augsburg as above, there were 306 days of rain on the day of the first octant, 325 on the day of the first quarter, 341 (the maximum) on the day of the second octant, 284 (the minimum) on the day of the last quarter, and 290 on the last octant. Some observations which appear to have been made under M. Arago's personal superintendence may be quoted in confirmation of the fact, that the greatest amount of cloud follows upon the moon's first quarter, and the least amount of cloud on the third quarter,—

"The discussion of the observations made at Paris led to the following conclusions:—

"The maximum number of rainy days is found to lie between the first quarter and the full moon; the minimum between the last quarter and the new moon; and the latter number is to the former as 100 is to 126*."

4. Having pointed out, very briefly, the periods at which (taking one lunation with another) the greatest amount of heat or cold is to be expected to recur, and having also suggested a probable cause for the phenomenon, I

* Arago's Popular Astronomy (Admiral Smyth's translation), vol. ii. p. 318. In the same volume, p. 313, there is the following passage in which Sir John Herschel's explanation of the moon's influence on the clouds is entirely adopted:—"In a word, provided we do not lose sight of the fact that the rays which dissipate the clouds are quite different from those whose calorific qualities we have been endeavouring to estimate at the instant when they reach the surface of the earth, the fact which I previously called a prejudice will no longer be contrary to physical laws; and we shall obtain an additional illustration of the remark, that popular opinion ought not to be rejected without examination."

propose to illustrate the subject by examples of lunar action in the spring and autumn months. Thus in the early part of May, it will be interesting to remark the amount of Lunar Influence exerted at the period of low temperature which embraces Dr. Mädler's three cold days, viz. the 11th, 12th, and 13th, and which on an average of 86 years' observations at Berlin was found to be more than 2 degrees colder than the calculated mean of the season. The following Table of mean temperatures of the first twenty days of May for 43 years at Greenwich, will show the amount of depression which occurred at that station. The means are in each case for the civil day.

1st, 50·3	2nd, 51·5	3rd, 50·9	4th, 51·5	5th, 51·8
6th, 51·9	7th, 52·3	8th, 52·1	9th, 51·0	10th, 50·9
11th, 51·6	12th, 51·3	13th, 51·0	14th, 50·6	15th, 51·9
16th, 53·1	17th, 54·0	18th, 53·5	19th, 53·0	20th, 53·9*

If we now examine a lunar curve (fig. 3) of the mean temperatures of the 11th, 12th, and 13th days at Greenwich,—they are purposely taken, though not the coldest,—it will not fail to be noticed that the general line of the wave, notwithstanding its pronounced character, follows the model curve, with the exception of a remarkable rise on the second day before first quarter, and on the second day before last quarter. It bears also a very close resemblance to the curve of temperature for the year 1859.

A lunar curve of the mean temperature for the month of May during 43 years has also been formed, and found to agree with the model curve; the mean of the means of the day of first quarter and five days after is 54·0, of the day of full moon and five days after 51°·9. The amount of cloud on a seven years' average for the second day after full moon is 4·9; for the second day after first quarter 8·1; and the mean amount of cloud at the syzygies and quarters for the day of the moon's change and the day preceding and following is as follows:—

At New Moon................	6·8
At First Quarter..............	6·9
At Full Moon................	5·7 (the minimum).
At Last Quarter..............	6·3

10 represents an entirely clouded sky.

On viewing these results one cannot but recall to mind the belief of the French gardeners in the ravages of "La Lune rousse" towards the end of April or beginning of May; and the explanation of the phenomenon given by M. Arago,—that it was, without doubt, due *to the absence of cloud.*

The observations of mean temperature at this period, however, and the relative number of days of the lunation on which they occur, deserve a more minute consideration. To facilitate it, Tables have been formed of the mean temperatures of five consecutive days at full moon, and five corresponding days at first quarter: and for the purpose of reference, a Table of the mean temperatures of the month of May for 43 successive years is appended.

On referring to these Tables, it will be at once perceived that the mean temperature of each of the five days at full moon (see Table II.) is far below that of the five days at first quarter (Table I); and also that the number of observations which occurred in the 43 years at the two periods is very different.

* From observations kindly furnished by Principal Forbes, of St. Andrews, it appears that the 9th, 10th, and 14th days of May were the coldest at Edinburgh on an average of 40 years. The 12th, 13th and 14th days, allowing for the estimated march of temperature, were the coldest days at Greenwich. It is possible that the epoch of greatest depression would in a longer series of years coincide with that at Berlin.

TABLE I.

Day.	1.	☽	1.	2.	3.	Mean.
10	1856. 52°·2	1829. 57°·1 1848. 61·1	....	1821. 51°·1 1840. 59·0 1851. 56·3	1832. 41°·7 1843. 49·3	53°·5
11	1837. 41·5	1856. 56·4	1829. 55°·6 1848. 63·7	....	1821. 56·8 1840. 47·5 1851. 56·1	53·9
12	1818. 50·8	1837. 42·8	1856. 50·7	1829. 54·6 1848. 65·1	....	52·8
13	1845. 49·9	1818. 51·1	1837. 42·8	1856. 53·0	1829. 53·8 1848. 64·9	52·6
14	1826. 47·8	1845. 50·8	1818. 49·4	1837. 43·8	1856. 49·3	48·2
15	1815. 57·1 1834. 60·5 1853. 50·4	1826. 48·6	1845. 51·3	1818. 51·4	1837. 45·2	52·1
Means	51·2	52·6	52·2	54·3	51·6	52·2
No. of Obs.	8	7	6	8	9	Sum 38

TABLE II.

Day.	1.	○	1.	2.	3.	Mean.
10	1816. 41°·4 1827. 46·8 1846. 54·3	1819. 58°·4	1838. 47°·5	1830. 47°·1	1849. 42°·2	48°·2
11	1835. 52·2 1854. 49·0	1816. 39·4 1827. 48·6 1846. 53·3	1819. 57·1	1838. 47·5	1830. 45·6	49·1
12	1824. 46·3 1843. 53·8	1835. 53·0 1854. 52·0	1816. 38·1 1827. 47·3 1846. 53·4	1819. 57·8	1858. 51·5	50·4
13	1832. 38·6	1824. 43·8 1843. 55·3	1835. 52·0 1854. 54·2	1816. 40·8 1827. 48·1 1846. 53·0	1819. 54·4	48·9
14	1851. 46·2	1832. 44·5	1824. 44·3 1843. 52·7	1835. 44·0 1854. 54·7	1816. 43·8 1827. 46·6 1846. 51·2	47·5
15	1840. 49·8	1851. 50·7	1832. 47·4	1824. 42·8 1843. 53·6	1835. 49·0 1854. 55·5	49·8
Means	47·8	49·9	49·4	48·9	48·9	49·0
No. of Obs.	10	10	10	10	9	Sum 49

At full moon the mean temperature of the 10th, 11th, 12th, 13th, 14th, and 15th days of the month of May is 49°·0, and the number of observations 49. At first quarter, upon the same six days, the mean temperature is 52°·2, and the number of observations 38. No observations whatever for 1st, 2nd, or 3rd days after first quarter occurred upon the 10th, 11th, and 12th days of May respectively during the 43 years.

Again, upon the five days of the lunation at full moon (see Table II.), out of the total number of 49 observations, 27 are found to fall below 50°, and 11 below 45°. At first quarter, out of the 38 observations, the number under 50° is 13 only: those under 45° do not exceed 5.

A point of some importance in connexion with the subject should be mentioned. It did not escape Gen. Sabine's notice, when engaged on the results of the Meteorological Observations at Toronto, that high mean temperatures prevailed on the 11th, 12th, and 13th days of May on the average of the years 1841–52, at that Station, and it has since been found that they prevailed also at Greenwich during the same period; the mean temperatures of the three days for the 12 years were respectively 53°·5, 53°·2, and 54°·1 instead of 51°·6, 51°·3, and 51°·0, which are the means of those days on an average of 43 years. It will be found that most of the high temperatures on the three days occurred in years when the mean temperature of May itself was high*. The mean of the month for 43 years is 53°.

5. At a corresponding period of the year in autumn, the temperature of the second half of lunations which fall in October is found as a rule to be uniformly low; on an average of 43 years it does not exceed 48°·9; whilst the mean of the first half (from new to full moon) is 50°·4. It was so in the present year; the difference between the mean temperature of four days at first quarter and the mean temperature of four days at last quarter was 23·5 degrees.

Upon extracting 14 of the lowest temperatures, or minima of 43 months of October, 13 were found to occur in the second half of the lunation between the day of full moon and the third day before new moon, and 9 of the number at and immediately following on last quarter. They occurred in the following years:—

1814. 38·0	1817. 37·7	1824. 36·4	1825. 37·8	1828. 39·5
1834. 36·9	1836. 28·4	1838. 36·0	1839. 34·7	1842. 35·6
1843. 35·8	1845. 37·9	1848. 38·0		

It is difficult to believe that the following dates are accidental: 1814, 1824, (and 1825), 1834, 1843; and 1817, 1828, 1838 (and 1839), 1848.

The maxima in October also arrange themselves systematically. There were 4 observations of mean temperature in 43 years which exceeded 62°. They occurred in the following days and years:—viz. in 1834 on the third day after new moon; in 1819 on the second day before full moon; and in 1848 and 1859 on the day of first quarter, and second day after. In 1839 the maximum was 59·7, and it occurred on the second day after new moon. The mean of the month of October for 43 years is 49°·6.—More than 75 per cent. of the maxima for the month are found to occur in the first half of the lunation.

Lastly, the amount of cloud in October for seven years has been extracted from the Greenwich Observations and formed into a Lunar Table. The mean amounts for the day preceding each of the four principal phases and

* *e. g.* the mean of the mean temperatures of the five days at first quarter which occur on the 14th of May exceeds the mean of the five days at full moon which fall on the same day of that month by ·7 of a degree only. But the mean temperature of May for the five years in which observations occurred on the above-named day at first quarter was not higher than 49°·8. In the instances at full moon it was 51°·6.

four following days (including in each case the day of the change) is as follows :—

At New Moon	7·1
At First Quarter	7·9 (the maximum).
At Full Moon	6·9
At Last Quarter	6·1 (the minimum).

The mean amount of cloud for the first 14 days of the lunation is 7·3 ; for the remaining 14 days, 6·4.

The figures follow with great precision the course of the model curve and also the curve of mean temperature for 1859.

It will be well to recall attention to the principle of alternation and reciprocity which so much affects the mean results of the moon's action.

Many instances of the recurrence of high *or* low temperatures upon the same day of the lunation were adduced at the Meeting at Leeds : the following is an amended abstract of some of the more remarkable examples.

In the two consecutive years commencing November 1846 and ending October 1848, maximum or minimum temperatures for the month occurred, in 1846–47, three times on the third day before new moon ; twice on the day after new moon ; three times on the third day after new moon ; twice on the third day before full moon ; twice on the second day before full moon ; and twice on the third day after full moon. In 1847–48, twice on the third day before new moon ; four times on the day of new moon ; twice on the second day before full moon ; twice on the day before full moon ; twice on the day of full moon ; twice on the third octant, or fourth day after full moon. Again, in the year 1846–47 there were, amongst others, the following remarkable instances of alternation between opposite phases of the moon :—in December the minimum of the month occurred on the third day before new moon ; in January the maximum on the third day before full moon ; in February the minimum on the third day before new moon. And again, the maximum in November 1848 fell on the day of new moon ; the minimum in December on the day of full moon. In addition to this, maximum and minimum temperatures were found to occur at intervals of rather more than seven days, and that for several successive months, viz. April, May, June, August, and September, or at other lunar intervals. In 1838, exactly ten years earlier, maxima or minima occurred twice on the third day after new moon ; three times on the day before full moon ; three times on the day of first quarter ; and three times on the day of last quarter. At the Cape of Good Hope, reciprocity of action and the recurrence of high and low temperatures was even more frequent and systematic. Thus, in 1855, eight out of the twelve maxima for the month occurred at first quarter, and nine of the twelve minima at new or full moon. In 1842, nineteen maxima and minima out of twenty-four occurred on eight days. In 1843, fifteen on seven days ; in 1844, seventeen on six days ; in 1845, eleven on four days. The recurrence of maxima and minima at Toronto and Madras was equally marked.

On extracting the maximum and minimum mean temperatures for the month, for the respective periods of 43 years at Greenwich, and 22 years at Dublin, it was found that more maxima occurred after the moon's first quarter than before ; the proportion of maxima to minima, on the *second* day after that phase, being more than 2 : 1 at both stations. So too on taking the twelve highest maxima and the twelve lowest minima at Greenwich for the same forty-three years, 48 per cent. of the whole number were found to occur on

7 days at first quarter, and *minima only*, with one exception, before the day of the change. Similar results were obtained from the observations taken at Toronto (from 1843 to 1848).

Notwithstanding this, it is certain that the rise in the curve at first quarter and other periods of the lunation is not caused by the presence of maximum temperatures so much as the ordinary means of the several days.

Though not at present able to prove the point, I may state my conviction that a close connexion will eventually be established between the occurrence of extreme temperatures (at the several periods of the lunation at which they may most probably be looked for) and the years of maximum and minimum of the solar spots. The year 1858–1859 has been already instanced as one that exhibits many noticeable examples of this increased action.

The inquiry will be proceeded with; though as a non-professed Meteorologist I much need both indulgence and assistance.

TABLE III.

Means of the month of May, for 43 years, at Greenwich.

1814.	48°·6	1825.	53°·6	1836.	52°·0	1847.	56°·4
1815.	54·7	1826.	50·0	1837.	47·8	1848.	59·7
1816.	48·8	1827.	52·7	1838.	50·7	1849.	54·0
1817.	47·9	1828.	54·3	1839.	49·9	1850.	51·3
1818.	52·5	1829.	54·5	1840.	53·5	1851.	50·9
1819.	54·2	1830.	54·7	1841.	56·8	1852.	51·5
1820.	52·0	1831.	52·8	1842.	53·2	1853.	52·0
1821.	49·4	1832.	51·5	1843.	52·2	1854.	50·9
1822.	55·8	1833.	59·4	1844.	52·9	1855.	48·8
1823.	54·7	1834.	56·9	1845.	49·4	1856.	49·5
1824.	49·5	1835.	52·9	1846.	51·6	Mean ...53°·0	

An Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association. By BALFOUR STEWART, *M.A.*

EARLY in 1857 the Government Grant Committee of the Royal Society voted £150 towards the expense of a set of Self-recording Magnetographs to be erected at the Kew Observatory of the British Association; the sum of £250 having been previously granted out of the Wollaston fund for the purpose of lighting the observatory with gas.

The late Mr. Welsh thereupon applied himself with much zeal to the task of constructing these magnetographs, and devised a plan which was transmitted to Mr. Adie, optician, 395 Strand, who undertook to make the instruments.

These were completed by Mr. Adie in a satisfactory manner, and were in operation in July 1857; by the beginning of 1858 all difficulties, whether of a mechanical or photographic nature, had been overcome, and since that date a continuous register of the magnetic elements has been obtained. With regard to the plan devised by Mr. Welsh, the best proof of its excellence is the nature of the results obtained, which may be judged of from an average specimen of the curves appended to this Report. Indeed, the superior definition and finish of the lines leaves hardly anything to be desired. Mr. Beckley, the engineer attached to the observatory, very skilfully devised the mechanical details in conformity with Mr. Welsh's plan, and prepared a working drawing of the instruments*.

Mr. Chambers (magnetical assistant at Kew Observatory) assisted in overcoming certain photographical difficulties that arose. He has since been in charge of the instruments, and has performed his task in a very efficient manner.

This Report is divided into five sections. In the first section a general and preliminary description is given of the principles of construction of the magnetographs. In the second, a detailed account is given of each of the instruments. In the third section the photographic process is described. In the fourth, the method of ascertaining the instrumental coefficients, and of tabulating from the curves, &c., is detailed; and in the fifth section certain improvements are mentioned which have been made on a set of magnetographs since constructed of the same kind as those described.

Section I. Preliminary Description.

The room in which the instruments are placed is one of the lower rooms of the observatory, the roof of which is not much above the level of the ground outside. It is well protected from damp by a vault which goes round the observatory, and is subject to very small changes of temperature, the mean daily range being within 1° Fahr., and the annual range about 20°, the thermometer varying from 50° Fahr. in winter to 70° Fahr. in summer. In shape the room is an octagon, of about 22 feet in diameter, with a height of about 17 feet. Daylight is only admitted through panes of orange-coloured glass, which have the effect of excluding the actinic rays.

Four pillars, A, B, C, D (see Plate 3. fig. 1), made of Portland stone, are firmly fixed into the floor. The centres of the pillars B, C, D are in a line perpendicular to the magnetic meridian, while the centres of pillars A and D are in the line of that meridian. The pillars A, B, and C support the three magnetographs, while the pillar D supports the recording cylinders and clockwork.

In Plate 3. fig. 1, we have a ground-plan of the instruments, and in fig. 2 an elevation of the same.

Referring to the Declination Magnetograph (Plate 3. fig. 1), *a* denotes the gas-flame which is the source of light; *b* is a bull's-eye lens, the object of which is to condense the light on a narrow vertical slit at *c*. The bull's-eye therefore enables the light to be nearly as effective as it would be if placed immediately behind the slit *c*, although in reality it is at a convenient distance from it.

After having passed the slit *c*, the light is conveyed through a covered tube until it reaches the plano-convex achromatic lens set vertically at *d*, having passed through which, it next falls on two semicircular mirrors which have their centre at *e*. The faces of these mirrors are exhibited in Plate 4. fig. 3, from which it will be seen that the lower mirror is firmly fixed to a marble slab, while the upper one, which is nearly, but not quite in contact with the lower, is attached to a delicately suspended magnet, and consequently moves with it. The light, after leaving the mirrors, is reflected in the direction *ef* through a piece of plane glass at *f*, and through a covered tube until it reaches a cylinder *h*, the axis of which is horizontal, and which is covered with sensitive paper.

The focal length of the lens *d* is such, that the point *h*, where the rays

* The drawings for the Plates attached to this Report were also made by Mr. Beckley.

strike the cylinder, is the conjugate focus to the slit *c*; we should therefore have an image of the slit *c* exhibited on the sensitive paper. As, however, our object is to produce a *dot* and not a *slit* of light, a hemicylindrical lens, having its axis horizontal and focus at the cylinder, is placed at *g*, so that the rays passing through it have the vertical slit of light which they would otherwise have formed on the cylinder compressed into a dot; in which state therefore the light falls upon the sensitive paper. But it is only when both the mirrors, the fixed and the moveable, are in *one* plane that we shall have *one* dot upon the cylinder. For if the plane of the one mirror is inclined at an angle to that of the other, the ray from the first mirror will not be reflected in the same direction as that from the second, and will consequently fall upon a different part of the cylinder. Two slits of light will in this case reach the hemicylindrical lens, and two corresponding dots of light will appear upon the sensitive paper which covers the cylinder. The distance between these two dots will be a measure of the angle between the two mirrors, and will consequently (the lower mirror being fixed, and the upper one moving with the magnet) indicate the position of the magnet from time to time.

The cylinder round which the sensitive paper is wrapped is moved round by clockwork once in every twenty-four hours, so that the dot belonging to the fixed mirror generates a straight line, while that belonging to the moveable mirror will describe a line corresponding to the movement of the magnet.

The arrangements of the horizontal-force instrument are in all respects similar to those of the declination magnetograph which has just been described, with this exception, that in the latter the magnet is in its natural direction, viz. perpendicular to *ef*, while in the former it is twisted into a direction at right angles to its natural position, and is now in the line *ef*.

The only difference which it is necessary here to notice between the vertical-force magnetograph and those which we have now described, is that in the vertical-force magnetograph the slit *c* is horizontal and the hemicylindrical lens and cylinder vertical, while the axis on which the moveable semicircular mirror, attached to the magnet, turns, is horizontal. The mirror of this magnetograph is exhibited in Plate 4. fig 5. One piece of clockwork is made to drive all the cylinders.

The principle of construction which we have now described seems to possess the following advantages:—

1st. The optical arrangements are such as to secure an exceedingly well-defined dot of light, and by means of suitable photographic appliances, an unexceptionable curve and base-line.

2nd. Should anything occur to change the position of the slit *c*, both the curve and the base-line will be equally displaced, so that the distance between them (with which only we are concerned) will remain precisely the same as before.

Thus too, by slightly altering the position of the slit each day, we may put two or even three days' curves on the same sheet.

3rd. The stone piers, &c. secure perfect steadiness to the apparatus, and the central arrangement presents the advantage that one piece of clockwork drives all the cylinders.

Section II. Detailed Description of the Instruments.

1. *Declination Magnetograph.*

The flame used is that of gas, the supply of which is kept constant by means of a water-regulator. The burner consists of a narrow slit about three-quarters of an inch long, and one-hundredth of an inch in breadth. It is placed endwise with respect to the lens, in consequence of which position, the light (coming from a stratum of flame three-quarters of an inch in depth) has its brilliancy greatly increased (see Plate 4. fig. 10 A).

The shape of the burner and the arrangement for supplying the flame with air, are in all respects similar to those used in a paraffin lamp, their application to gas having been suggested by Mr. Beckley. The burner is fitted with a glass chimney, the presence of which intensifies the light—it must not, however, fit too tightly.

The bull's-eye lens used for condensing the light of the gas upon the slit is that known as the double condenser.

Having passed the bull's-eye lens, the light falls upon the slit *c*. The breadth of this slit is about $\frac{1}{100}$th of an inch; a front view of it is given in Plate 4. fig. 10 *a*.

By means of an adjustment, the distance between the gas-flame and the bull's-eye lens may be altered until the slit is in focus for the gas-flame.

The light having passed the slit, goes through a covered tube until it reaches the plano-convex achromatic lens before mentioned. By means of an adjustment, the gas-flame, the bull's-eye, and the slit may be moved together until the slit be at that distance from the lens which is the conjugate focus of the sensitive paper. There is also an arrangement by which gas, bull's-eye, and slit may be moved a little to one side of the central line of the lens, so that the two dots may be made to assume a different position on the sensitive paper.

The distance between the slit and the lens is 17·7 inches. This lens is fitted into a glass shade which covers the magnet, as represented in Plate 4. fig. 2.

This glass shade stands upon a circular marble slab, diameter 20 inches, thickness 1·2 inch, which is cemented to the top of a solid pillar of Portland stone 4 feet high.

There are two holes cut in this glass shade, each about 3 inches in diameter (see Plate 4. figs. 1 & 6), the one to contain the lens above mentioned, through which the rays of light pass on their way from the slit to the mirror; and the other to contain a piece of plane glass through which the same rays pass on their way from the mirror to the cylinder. The glass shade is gilded inside nearly to the top. This gilding serves the double purpose of reflecting back any heat associated with light which may strike it from the outside, and (being a bad radiator) of diminishing as much as possible the currents of air which changes of temperature are apt to produce. The portion of the shade which is not gilded is covered outside with a cloth cap, removeable at pleasure. A vessel containing chloride of calcium is put inside to absorb all moisture. A curved arm of brass (Plate 4. figs. 3 & 4) carries the suspension roller A, and torsion circle C (see also fig. 14) reading to minutes. The suspension thread is a silk fibre slightly rubbed with bees-wax, in order to render it less susceptible to hygrometric influences.

The magnet (D) is a rectangular bar about 5·4 inches long, 0·8 inch broad, and 0·1 inch thick. The semicircular mirrors, already alluded to, are also represented in figs. 3 & 4. Their diameter is 3 inches; and great care has been taken that the glass surfaces should be accurately plane and parallel to each other. G is a copper damper, the object of which is to check the oscillations of the magnet, and bring it to rest speedily. The angle *aef* (Plate 3. fig. 1) being $=30°$ and *ef* being perpendicular to the magnetic meridian, it follows that the plane of the mirror must be inclined at an angle of 15° to the axis of the magnet, in order that the ray *de* may be reflected in the direction *ef*.

The semicircular mirrors must likewise be placed so that their centre shall be on a level with the centre of the lens. The distance from the lens to the centre of the mirror is 8·1 inches. Having been reflected by the mirror, the light passes through a zinc tube fixed to a slate, which connects the declination pillar with the central pillar (see Plate 3. fig. 2), and so reaches the hemicylindrical lens and sensitive paper already described. The distance from the centre of the mirror to the sensitive paper is $6\frac{1}{2}$ feet. Hence we have

Distance between lens and mirror	= 8·1 inches.
Distance between mirror and cylinder ..	=78·0 inches.
Total distance between lens and cylinder	=86·1 inches.

And since the distance between the slit and the lens is 17·7 inches, we find that the focal distance of the lens for parallel actinic rays is nearly 14·7 inches*.

Before falling on the sensitive paper, the light passes through a hemicylindrical plano-convex lens (see Plate 3. fig. 1). The radius of the second surface of this lens, is about 0·6 inch, and consequently the distance between this surface and the sensitive paper (in order that the latter may be in focus) is nearly 1·2 inch.

2. *Horizontal-force Magnetograph.*

This instrument is exhibited in Plate 4. figs. 1 & 2. The magnet, mirror, lens, shade, adjustments of light and slit, &c., are in all respects similar to those of the declination magnetograph already described. The peculiarity of the instrument consists in the mode of suspension. A grooved wheel, E (Plate 4. figs. 1 & 2), about 0·3 in. in diameter, has its axle attached to the stirrup which carries the magnet, the plane of the wheel being in the direction of the magnet's length.

The suspension thread, consisting of steel wire (steel being considered little liable to stretch), is carried round the wheel, and the two ends fixed to the suspension roller A (see also fig. 13). A little below the suspension roller the two threads pass over a screw at B, the screw being right-handed where it meets the one thread, and left-handed where it meets the other. Consequently by turning the screw-head, we can vary the distance between the wires until it becomes equal to the diameter of the wheel, and the wires will now be at the same distance from one another throughout their entire length. Let us suppose that the magnet is in the direction of the magnetic meridian. Turn round the torsion circle C (precisely similar to that already described) until the magnet assumes a position at right angles to the magnetic meridian. It is clear that, in order to do this, we shall have to turn the torsion circle through an angle greater than 90°, and consequently that the plane of the wires at their lower extremity will be different from that at their upper. This difference is at present =35° 56′ nearly. The suspension thread is about 11·6 inches long.

As the light which falls upon the mirror in the direction *de* (see Plate 3. fig. 1) must be reflected in the direction *ef* (*def* being 30° as before), it follows that the plane of the mirror must make an angle of 75° with the magnetic axis of the magnet.

The distance between the slit and the lens is 17·7 inches, and that between

* The focal length of the lens is determined rather by convenience of shape of the instrument than by optical considerations. In the declination magnetograph, for instance, if the distance between the slit and the lens were much greater than 17·7 inches, the light, bull's-eye, and slit could not well be supported by an arm of the slate which is attached to the declination pillar, but would require a separate pillar for themselves.

the lens and the mirror 8·1 inches, these being the same as in the declination magnetograph; but the distance between the centre of the mirror and the cylinder is different, being here 4·885 feet.

Hence the focal length of the lens for parallel actinic rays is about 14 inches. The hemicylindrical lens is in all respects similar to that already described.

3. *Vertical-force Magnetograph.*

This instrument is exhibited in Plate 4. figs. 5, 6 & 7.

The vertical-force magnet is of the same size as the others, and is balanced by means of a steel knife-edge upon an agate-plane. It is provided (see Plate 4. fig. 7) at one side with a brass screw working horizontally, and at the other with a similar screw working vertically. By means of these the centre of gravity may be thrown to either side of the centre of suspension, or it may be raised or lowered, and the sensibility of the magnet, when balanced, thereby increased or diminished.

These screws are arranged so that there is a preponderance of weight towards the south side of the magnet. This is neutralized partly by the magnetic force tending to pull the north end down, and partly by a slip of brass (H) standing out horizontally towards the north side. Let us suppose the system to be in equilibrium at a certain temperature; if the temperature rise (since brass expands more than steel), the leverage of the weight at the north side will increase more rapidly than that of the weight at the south. There will therefore be a slight preponderance towards the north, and this may be arranged so as to neutralize to a great extent the decrease in the magnetic moment which an increase of temperature produces.

The plane of the magnet is 15° out of the magnetic meridian (see Plate 3. fig. 1), for the following reason. Had the magnet been in the magnetic meridian, it would have been necessary to have placed the mirror inclined at an angle of 15° to the axis of motion of the magnet. This was tried, but it was found that in this position of the mirror, the correction for temperature was so excessive that the instrument became a thermometer, and not a magnetometer. The mirror was therefore put in a plane passing through the axis of motion of the needle, the needle being made to move in a plane inclined 15° to the magnetic meridian. Its temperature correction is at present very small.

The mirror of this instrument is exhibited in Plate 4. fig. 5, one half moving with the magnet, and the other half being fixed to a stand; I is a lifter which may be inserted from without the glass shade, and which, by raising three Ys to catch the needle, may remove it from its position of balance when necessary.

A thermometer is inserted within the glass shade of this instrument, by means of which the temperature both of the horizontal and the vertical-force magnets may be determined with sufficient accuracy.

In the vertical-force magnetograph, the slit for the light is horizontal, while the hemicylindrical lens and the cylinder are vertical.

It might be thought that with a horizontal slit the style of burner already described would prove unsuitable, as we here require a horizontal and not a vertical light; but by using a burner twice as large every way as those of the other magnetographs, we obtain a light that is found to answer in practice extremely well.

The adjustments for regulating the distance between the light and the slit, and between the slit and the lens, are similar to those for the declination and bifilar magnetographs. There is also an adjustment, by means of which the light, bull's-eye, and slit may be pushed vertically (not horizontally as in the others) a little to one side of the central line of the lens, so that the dots may assume a different position on the sensitive paper.

The distance between the slit and the lens is 17·6 inches, that between the lens and the mirror is 8·1 inches, while the distance between the mirror and the cylinder is 6 feet.

Hence the focal length of the lens for actinic parallel rays is about 14·4 inches.

4. *Registering Cylinder and Clockwork.*

These are exhibited in Plate 4. figs. 8 & 9. The cylinders are each 6½ inches long, and 6 inches in diameter. They consist of brass silvered over. The method of connecting them with the clockwork was devised and executed by Mr. Beckley. The toothed wheel *k* is driven by the clockwork, and drives the two pinions *l*. These pinions, when in gear, drive the two horizontal cylinders by means of teeth attached to the circumference of the latter. Two radial arms, to which the pinions *l* are attached, enable these to be put out of gear when it is necessary to remove the cylinders. The position of the pinions in this case is indicated in the figure by dotted lines. The vertical cylinder has a toothed rim attached to its lower extremity, which is driven by the crown wheel *m*. By removing a screw, the cylinder may, when necessary, be detached from its toothed rim, leaving the latter behind.

Section III. Description of the Photographic Process.

The process employed is that known as the waxed-paper process, and is thus described by Mr. Crookes.

Description of the Wax-paper Photographic Process employed for the Photometeorographic Registrations at the Radcliffe Observatory. By W. Crookes, *Esq.*

1. Before attempting to select from the numerous Photographic processes the one best adapted to the requirements of Meteorology, it was necessary to take into consideration a number of circumstances comparatively unimportant in ordinary operations.

To be of any value, the records must go on unceasingly and continuously :

First. Therefore, the process adopted must be one combining sharpness of definition, with extreme sensitiveness, in order to mark accurately the minute and oftentimes sudden variations of the instruments.

Second. To avoid all hurry and confusion, it is of the utmost importance that the prepared paper or other medium be of a kind capable of retaining its sensitiveness for several days.

Third. The contraction which paper undergoes during the numerous operations to which it is subject in most processes (in general rather an advantage than otherwise), is here a serious objection; for this reason, the experiment first tried, of transferring to paper the image received on collodion preserved sensitive by the nitrate of magnesia process, was a failure.

Fourth. Strong contrast of light and shade, and absence of half-tint, unfortunately so common amongst ordinary photographic pictures, is in this case no objection.

Fifth. It is essential to preserve the original results in an accessible form; and for this reason, the Daguerreotype process, admirably as it seems to answer other requisites, is obviously not the one best suited to our purpose.

Lastly, the whole operation should, if possible, be so easily reducible to practice, that with a very small share of manipulatory skill, the loss of even a day's record would be impossible.

2. Bearing these conditions in mind, on looking over the photographic processes with which I was acquainted, that known as the wax-paper process, first described by M. Le-Gray, seemed peculiarly applicable. In sharpness it might be made to rival collodion; and although generally stated to be slow in its action, I had no doubt that its sensitiveness could be easily increased to the required degree.

Of all paper processes, I believed it to be the one most free from contraction, either during the time it is undergoing the action of the light, or in any subsequent stage. Its chief superiority, however, consisted in its capability of remaining sensitive for so long a time, that it is of little consequence whether the sensitive sheets be a day or a week old. Then the comparative slowness of the development, which has always been looked upon as one of its weak points, would be in this case a positive advantage, as dispensing with that care and attention which must always be bestowed on a quickly developing picture.

In addition to all these recommendations, it was a process to which I had paid particular attention, and consequently the one in which I might naturally hope to meet with the greatest amount of success.

3. The general outline of the process does not differ materially from that which I published some years back in 'Notes and Queries,' vol. vi. p. 443; but as that account was written for practical photographers, the details of the manipulation were brief. It has therefore been thought advisable, that while describing again the whole process, with the addition of such modifications as the end in view requires, I should also give such fuller description of the manipulation, as may render it more serviceable to those who have not hitherto paid attention to photography in its practical details. This must be my excuse, if to some I seem unnecessarily prolix. None but a practical photographer can appreciate upon what apparently trivial and unimportant points success in any branch of the art may depend.

It may not be without service, if, before entering into the practical details of the process, I say a few words respecting the most advantageous way of arranging a photographic laboratory, together with the apparatus, chemicals, &c. which are of most frequent use.

Among those requisites, which may be almost called absolute necessaries, are gas, and a plentiful supply of good water, as soft as can be procured.

4. The windows and shutters of the room should be so contrived as either to allow of their being thrown wide open for purposes of ventilation, or of being closed sufficiently well to exclude every gleam of daylight; and the arrangement should admit of the transition from one to the other being made with as little trouble as possible.

5. A piece of very deep orange-coloured glass, about 2 feet square, should be put in the window, and the shutter ought to be constructed so as to allow of the room being perfectly darkened, or illuminated, either by ordinary daylight, or daylight which has been deprived of its photographic rays, by filtering through the orange glass. The absorbing power of this glass will be found to vary very considerably in different specimens, and I know of no rule but experience to find out the quality of any particular sample; the best plan is to select from a good stock one of as dark a colour as possible. The proper colour is opake to the rays of the solar spectrum above the fixed line E.

6. The best source of heat is unquestionably gas. It will be as well, however, to have a fire-place in the room, as, in some cases, a gas-stove will be

inapplicable. There should be gas-burners in different parts of the room for illumination at night; and also an arrangement for placing a screen of orange glass in front of each.

Several rough deal benches should be put up in different parts of the room, with shelves, drawers, cupboards, &c. The arrangement of these matters must of course depend upon the capabilities of the room.

7. The following apparatus is required. The quantities are those that we have found necessary in this Observatory:—

Eight dishes.
Eight mill-board covers.
Three brushes for cleaning dishes.
A vessel for melting wax.
Two gauze burners.
One box, iron.
Filtering paper.
A still for water.
One platinum, and three bone spatulas (flat paper-knives).
Six funnels.
One funnel stand.
Pint, half-pint, one ounce, and one drachm measures.
Three glass flasks.
Boxes for holding paper.
Scales and weights.
Sponge, glass rods, stoppered bottles, &c.

8. The dishes may be made of glass, porcelain, or gutta percha. Glass and porcelain are certainly cleaner than gutta percha; but for general use the latter is far preferable, as with it there is no risk of breakage, and the bottom of the dish can be made perfectly flat, which is a great advantage. These dishes should be made of sufficient length to allow of a margin of about half an inch at each end when the paper is in; and the shape should be made as nearly square as possible, by arranging them to take two or three sheets side by side.

The gutta percha should be of a good thickness, otherwise it will bend and give way, if it be moved when full of liquid. The depth must depend upon the size of the dish, and the purpose for which it is intended. The dishes in use here accommodate three sheets of paper side by side; they are fifteen inches square, and one inch and a half deep. I think, however, for some purposes, where they are not wanted to be moved about much (*i.e.* those for holding the bath of hyposulphite of soda for fixing), the depth might be advantageously increased to two inches and a half. Each dish ought to be reserved for a particular solution, and should have a piece of millboard a little larger than itself for a cover.

9. The brushes for cleaning the dishes are of two sorts; a common scrubbing brush will be found the best for all parts but the corners, and for these another kind must be used, having a handle about a foot long, at the end of which are tufts of stiff bristles, projecting about three-quarters of an inch, and radiating on all sides, forming a ball about two inches and a half in diameter. Hardly any dirt will be found capable of resisting this brush if it be pressed into a corner, and twisted round several times. The dishes ought always to be put away clean, as the dirt is much more difficult to remove if allowed to dry on.

10. When a dish is to be cleaned, if it be of glass or porcelain, strong nitric acid must be poured into it; if of gutta percha, it should be filled with a strong solution of cyanide of potassium. After soaking for half an hour or an hour, according to the state of the dish, the liquid is to be returned into the bottle (both the nitric acid and the cyanide can be used several times), the dish rinsed out with water, and then well scrubbed in every part with the brushes; afterwards it is to be washed several times in common water, once with distilled water, and then placed in a slanting position against a wall, face downwards, to drain on clean blotting-paper.

11. The vessel in which the wax is melted, must be contrived so as never to allow of its reaching a higher temperature than 212° Fahr., or decomposition of the wax might ensue. I have found the most convenient apparatus to be, a tin vessel 15 inches square and 4 inches deep, having a tray which holds the wax fitting into it about 1 inch deep. The under vessel is to be half filled with water, and by keeping this just at the boiling temperature, the wax above will soon become liquid.

12. The best source of heat is that known as the gauze gas-burner, it being free from smoke or dust, and not liable to blacken anything placed over it. It consists of a common argand burner fixed on a rather low and heavy iron stand, which is surmounted by a copper or brass cylinder 5 inches in height and 2 inches wide, having a piece of wire gauze of 900 meshes to the square inch fastened over the top. By connecting this burner by means of vulcanized india-rubber tubing to the gas-pipe, it can be moved about the table to any convenient position. The mixture of gas and air, formed inside the cylinder, is to be lighted above the wire gauze; it burns over this with a large and nearly colourless but intensely hot flame.

13. The most convenient form of iron is the ordinary box iron, made hot by heaters inside; perhaps it might be improved in shape by having the end not quite so pointed, but this is not of much consequence. Some operators recommend facing the bottom with a plate of silver; this is very expensive, and seems to me to be attended with no advantage whatever.

14. For the purpose of absorbing the excess of wax from the surface of the sheet, I should recommend the ordinary white wove blotting-paper, medium thickness. But this is not sufficiently free from impurities to serve either for drying the sensitive sheets, or for filtering; for this purpose, the fine filtering paper (not the Swedish) employed in quantitative chemical operations is the best.

15. The distilled water being one of those substances upon the purity of which success will in a great measure depend, it will be found much safer to distil it on the premises, especially as the quantity required is trifling. A convenient size for the still is about two gallons; it may be procured ready made, with worm, &c. complete, of any large dealer in chemical apparatus. It will be found far more economical, both in time and trouble, to heat the water over a charcoal or coke fire, in preference to using gas for this purpose.

16. A platinum spatula is a most necessary instrument in almost every operation; the best size is 4 inches long, $\frac{1}{2}$ an inch wide at one end, and $\frac{3}{8}$ at the other, the corners being rounded off; it should be of a sufficient substance to prevent its being easily bent. It chief use is to raise one corner of the sheets to allow of their being held between the finger and thumb, for the purpose of removing from one dish to another, as, previous to fixing, none of the solutions should come in contact with the fingers.

During the fixing and subsequent washing, bone spatulas will be found very useful; but after having been in contact with hyposulphite of soda, they must be carefully kept away from any of the previous baths, or black stains will infallibly ensue.

17. The funnels may be either of glass or porcelain; it will be found useful to have several of different sizes, from 2 inches diameter, up to 6 inches. A convenient stand for them may be made of a piece of flat board, with circular holes, about half the diameter of the funnels employed, drilled into it, and supported upon four legs about 8 inches high. The paper used for filtering should be the finest of the two sorts of blotting-paper mentioned above (14). The filters can either be cut from the sheet as wanted, or they may be obtained ready cut in packets.

The measures should be of glass, graduated, the pint and half pint into ounces, the ounce measure into drachms, and the drachm measure into minims; they shonld be rather long in proportion to their width.

The Florence oil-flasks, which can be obtained for a trifle at any oil warehouse, will be found to answer every purpose, nearly as well as the more expensive German flasks. They must be cleansed thoroughly from the adhering oil; this may be done by boiling in them, over the gauze gas-burner, a strong solution of ordinary washing soda, and afterwards well rinsing out with water.

18. It will be found indispensable, where there are many operations going on at the same time, and many different sheets of paper in various stages of progress, to have a separate box or division to hold the paper in each of its stages. The plan I have found most convenient, is to obtain several mill-board boxes, the fronts of which will fall flat when the lid is lifted up, similar to those used by stationers for holding letter paper, &c.: they can be made to hold two or three piles of sheets side by side. They may be obtained from M. Rousseau, 352 Strand, London.

The scales and weights need not be of any great accuracy. A 6-inch beam capable of turning to half a grain, when loaded with 500 grains in each pan, will be all that is requisite: the pans must be of glass, and the weights should consist of a set of grain and a set of drachm weights.

A sponge will be found useful for wiping up any of the solutions that may have been spilt on the bench. Solid glass stirring rods of about the thickness of a quill, and six or eight inches long, and a small Wedgewood pestle and mortar, are of great service in many of the operations.

Stoppered bottles should be employed for all the solutions; and too much care cannot be taken to label each bottle accurately and distinctly.

19. Besides the above apparatus, the following materials and chemicals are requisite. A rough estimate is also given of their relative consumption in three months:—Photographic paper, 270 sheets, or 112 square feet; four pounds of wax; three ounces of iodide of potassium; three ounces of bromide of potassium; four ounces of nitrate of silver; two ounces of glacial acetic acid; four ounces of gallic acid; one pint of alcohol; seven pounds of hyposulphite of soda; half a pound of cyanide of potassium; half a pint of concentrated nitric acid; eighteen gallons of distilled water.

20. The selection of a good sample of paper for the basis on which the sensitive material is to be formed is of great importance, as any imperfection will be a source of annoyance in every stage of the process, and will hardly fail to show itself on the finished picture. The paper, which from numerous experiments I have found to be superior to any other, is that known as Canson's thin photographic paper. This is manufactured with care, and is in general very uniform in quality.

It will be found by far the most advantageous plan, when used on a scale like the present, to order it of some wholesale stationer cut to the requisite dimensions. The size of the sheets in use here is $4\frac{5}{8}$ inches by $12\frac{1}{12}$ inches*. Hitherto Messrs. Hallifax and Co., 319 Oxford Street, have supplied us with the paper of this size.

21. I am indebted to Mr. Barclay of Regent Street, wax bleacher, for much valuable information concerning wax and its adulterations, and for

* This is a most inconvenient size, as it involves the cutting of more than one-third of the paper to waste. The admirably ingenious arrangement of Mr. Ronalds was not made with the view of employing Canson's paper, or it would doubtless have been contrived t accommodate sheets of a size which could be cut with less waste, such as $4\frac{1}{4}$ by 13 inches or $4\frac{3}{8}$ by $11\frac{1}{4}$ inches.

an extensive assortment of waxes of all kinds, and in every degree of purity; also to Mr. Maskelyne, for a valuable series of the chemical bodies of which the various waxes are composed; by means of these I have been enabled to examine the effect produced by saturating the paper with bees-wax from different countries, Myrica wax, Canauba wax, China wax, spermaceti, ethal, stearic acid, stearin, palmitic acid, palmitin, paraffin, and various oils.

22. I find that the action of the wax is purely mechanical, almost the only difference of effect produced by any of the above bodies, widely as they vary in their chemical nature, arising from a difference in their physical properties.

Stearin, palmitin, and most of the oils, are too greasy in their nature to be advantageously employed. The fatty acids do not make the paper in the least greasy, but they injure the transparency. China wax has almost too high a melting-point, and gives a crystalline structure to the paper. Spermaceti also is too crystalline. Paraffin, ethal, and the waxes, produce very good results; of these bees-wax is the only one that would be practically available for this purpose. It should be free from stearin, stearic acid, tallow, &c.; the presence of a little spermaceti does not much interfere, but as its price does not differ very much from that of pure wax, it is not so common an adulteration as the other cheaper substances.

23. It will be unsafe to use the wax in the form of round thin tablets, about 4 inches in diameter, in which it is usually met with, as in this state it is generally adulterated to the extent of *at least* 50 per cent.

As an article of commerce, it is next to impossible to obtain small quantities of wax sufficiently pure to be relied upon. The only way I can recommend is to apply to one of the well-known large bleachers, and trust to them for supplying the article in a state of purity. Whenever I have found it necessary to make such applications, my request has always been acceded to in the most cordial manner, and every information has been given with the utmost readiness.

24. The other chemicals (with the exception of the strong nitric acid, which any retail druggist will supply, and the water, which had best be distilled on the premises) should be ordered direct from some manufacturing chemist, as otherwise, unless the operator have a sufficient knowledge of chemistry to be able to detect any inferiority, there is danger of not having the articles sufficiently pure.

The iodide and bromide of potassium should be ordered *purified*.

The nitrate of silver should be crystallized, not in sticks; it ought to be perfectly dry, and have no smell, acid or otherwise.

There are usually two varieties of glacial acetic acid to be met with; the purest must be used; it should be perfectly free from any empyreumatic odour, and must cause no turbidity when mixed with a solution of nitrate of silver, *e. g.* in making the exciting bath (42).

The gallic acid should be as nearly white in colour as possible.

Especial care should be taken to have the alcohol good; it should be 60° over proof, and of specific gravity 0·83. On evaporating a few drops on the palm of the hand, no smell should be left behind, nor should it, under the same circumstances, leave any stain on a sheet of white paper.

25. The hyposulphite of soda will be found one of the articles most difficult to obtain pure; there is a large quantity at present in the market, having little else of this salt but the name, and being of course totally unfit for use; if there be the least doubt about its purity, it should be tested in the following manner:—

Weigh out accurately 10 grains of nitrate of silver, dissolve this in half an ounce of distilled water; then add 4 grains of chloride of sodium (common salt), also dissolved in water. On mixing these two solutions together, a white curdy precipitate of chloride of silver will fall down. Next add 22 grains of the hyposulphite of soda, and allow it to stand for about ten minutes, stirring occasionally with a glass rod. If at the end of that time the chloride of silver has dissolved, the hyposulphite of soda may be considered as pure. A greater or less amount of residue will indicate roughly the degree of impurity.

26. The cyanide of potassium is usually met with in the form of hard white lumps; they will be found quite pure enough. It is very useful in removing stains formed by nitrate of silver on the fingers, &c.; but the greatest care must be taken in its employment, as it is a most energetic poison; its use in cleaning the dishes from silver stains has been pointed out above (10).

27. The first operation to be performed is to make a slight pencil mark on that side of the photographic paper which is to receive the sensitive coating. If a sheet of Canson's paper be examined in a good light, one of the sides will be found to present a finely reticulated appearance, while the other will be perfectly smooth; this latter is the one that should be marked. Fifty or a hundred sheets may be marked at once, by holding a pile of them firmly by one end, and then bending the packet round, until the loose ends separate one from another like a fan; generally all the sheets lie in the same direction, therefore it is only necessary to ascertain that the smooth side of one of them is uppermost, and then draw a pencil once or twice along the exposed edges.

28. The paper has now to be saturated with white wax. The apparatus for this purpose has been previously described (11). The wax is to be made perfectly liquid, and then the sheets of paper, taken up singly and held by one end, are gradually lowered on to the fluid. As soon as the wax is absorbed, which takes place almost directly, they are to be lifted up with rather a quick movement, held by one corner and allowed to drain until the wax, ceasing to run off, congeals on the surface. When the sheets are first taken up for this operation, they should be briefly examined, and such as show the water-mark, contain any black spots*, or have anything unusual about their appearance, should be rejected.

29. The paper in this stage will contain far more wax than necessary; the excess may be removed by placing the sheets singly between blotting-paper (14), and ironing them; but this is wasteful, and the loss may be avoided by placing on each side of the waxed sheet two or three sheets of unwaxed photographic paper, and then ironing the whole between blotting-paper; there will generally be enough wax on the centre sheet to saturate fully those next to it on each side, and partially, if not entirely, the others. Those that are imperfectly waxed may be made the outer sheets of the succeeding set. Finally, each sheet must be separately ironed between blotting-paper until the glistening patches of wax are absorbed.

30. It is of the utmost consequence that the temperature of the iron should not exceed that of boiling water. Before using, I always dip it into water until the hissing entirely ceases. This is one of the most important points in the whole process, but one which it is very difficult to make beginners properly appreciate. The disadvantages of having too hot an iron, are not

* These spots have been analysed by Mr. Malone; he finds them to consist, not of iron, as is generally supposed, but of small pieces of brass. I have also examined them myself with a like result.

apparent until an after stage, while the saving of time and trouble is a great temptation to beginners. It is to a neglect of this point that I am inclined to attribute most of the faults so commonly laid to the charge of this beautiful process; such as gravelly appearance, or want of smoothness in the lights, and quick decomposition in the developing solution.

31. A well-waxed sheet of paper, when viewed by obliquely reflected light, ought to present a perfectly uniform glazed appearance on one side, while the other should be rather duller; there must be no shining patches on any part of the surface, nor should any irregularities be observed on examining the paper with a black ground placed behind; seen by transmitted light, it will appear opalescent, but there should be no approach to a granular structure. The colour of a pile of waxed sheets is slightly bluish.

32. The paper, having undergone this preparatory operation, is ready for *iodizing*; this is effected by completely immersing it in an aqueous solution of an alkaline iodide, either pure or mixed with some analogous salt.

One would think that in no part of the photographic operation would greater unanimity exist, than on the composition of the iodizing bath; but on this subject, strangely enough, no two persons seem to think alike. The formulæ for this bath are nearly as numerous as the operators themselves; and some of them show not a little ingenuity in the manner in which substances apparently the most unphotographic have been pressed into service.

33. The results of numerous experiments, which I need not mention here, had convinced me, that for ordinary purposes, iodide of silver *per se* was the best sensitive surface for receiving an image in the camera; but on making use of that body in these operations (by employing pure iodide of potassium in the bath), I was surprised to meet with results for which I was at first unable to account. A little consideration, however, showed me the direction in which I was to look for a remedy. The experiments which had led me to prefer iodide of silver as a sensitive surface, had all been performed with sunlight, either direct, or more frequently in the form of diffused daylight. In this case, however, coal-gas was the source of light; and if, as was very probable, there were any great difference in the quality of the light from these two sources, the superiority of iodide over the bromide or chloride of silver would still be a matter for experiment.

34. A comparison of the spectra of the two kinds of light showed a very marked difference; while in sunlight the spectral rays which are around and above the fixed line G (the indigo and higher rays) are so intense and numerous, as completely to overpower the small space between and about F and G (the blue and upper portion of the green), a part of the spectrum which affects bromide more than iodide of silver; in gaslight the case was quite different. The great bulk of photographic rays was found to lie within the limits of the visible spectrum, and consequently the photographic action of this light was likely to be far more energetic on bromide than on iodide of silver. These suppositions were fully borne out by experiment: on introducing a little bromide of potassium into the iodizing bath, the change was very apparent. It requires a certain proportion to be observed between the two to obtain the best results. If the iodide of potassium be in excess, the resulting silver salt will be wanting in sensitiveness, requiring a comparatively long development to render an image visible; while, if the bromide be in excess, there will be a great want of vigour in the impression, the picture being red and transparent. When the proportion between the two is properly adjusted, the paper will be extremely sensitive, the picture presenting a vigorous black appearance, without the least approach to red. The addition of a chloride was found to produce a somewhat similar effect to that

of a bromide, but in a less marked degree. As no particular advantage could be traced to it, it was not employed.

35. I have also tried most of the different forms of organic matter which it is customary to add to this bath, but I cannot recommend them; the most that can be said is, that some of them do no harm. At first I thought a little isinglass might be an improvement, as it instantly removes the greasiness from the surface of the paper, and allows the iodide of potassium to penetrate more readily. Unfortunately, however, it interferes with the most important property of this process, that of remaining sensitive for a long time.

36. I think the best results are obtained when the iodide and bromide are mixed in the proportion of their atomic weights; the strength being as follows:—

Iodide of potassium	582·5 grains.
Bromide of potassium	417·5 grains.
Distilled water	40 ounces*.

When the two salts have dissolved in the water, the mixture should be filtered; the bath will then be fit for use.

37. At first a slight difficulty will be felt in immersing the waxed sheets in the liquid without enclosing air-bubbles, the greasy nature of the surface causing the solution to run off. The best way is to hold the paper by one end, and gradually to bring it down on to the liquid, commencing at the other end; the paper ought not to slant towards the surface of the bath, or there will be danger of enclosing air-bubbles; but while it is being laid down, the part out of the liquid should be kept as nearly as possible perpendicular to the surface of the liquid; any curling up of the sheet, when first laid down, may be prevented by breathing on it gently. In about ten minutes the sheet ought to be lifted up by one corner, and turned over in the same manner; a slight agitation of the dish will then throw the liquid entirely over that sheet, and another can be treated in like manner.

38. The sheets must remain soaking in this bath for about three hours; several times during that interval (and especially if there be many sheets in the same bath) they ought to be moved about and turned over singly, to allow of the liquid penetrating between them, and coming perfectly in contact with every part of the surface. After they have soaked for a sufficient time, the sheets should be taken out and hung up to dry; this is conveniently effected by stretching a string across the room, and hooking the papers on to this by means of a pin bent into the shape of the letter S. After a sheet has been hung up for a few minutes, a piece of blotting-paper, about one inch square, should be stuck to the bottom corner to absorb the drop, and prevent its drying on the sheet, or it would cause a stain in the picture.

39. While the sheets are drying, they should be looked at occasionally, and the way in which the liquid on the surface dries, noticed; if it collect in drops all over the surface, it is a sign that the sheets have not been sufficiently acted on by the iodizing bath, owing to their having been removed from the latter too soon. The sheets will usually during drying assume a dirty pink appearance, owing probably to the liberation of iodine by ozone in the air, and its subsequent combination with the starch and wax in the paper. This is by no means a bad sign, if the colour be at all uniform; but if it appear in patches and spots, it shows that there has been some irregular

* While giving the above as the calculated quantities, I do not wish to insist upon their being adhered to with any extreme accuracy. An error of a few grains on either side would, I believe, be without any perceptible effect on the result.

absorption of the wax, or defect in the iodizing, and it will be as well to reject sheets so marked.

40. As soon as the sheets are quite dry, they can be put aside in a box for use at a future time. There is a great deal of uncertainty as regards the length of time the sheets may be kept in this state without spoiling; I can speak from experience as to there being no sensible deterioration after a lapse of ten months, but further than this I have not tried.

Up to this stage it is immaterial whether the operations have been performed by daylight or not; but the subsequent treatment, until the fixing of the picture, must be done by yellow light (5).

41. The next step consists in rendering the iodized paper sensitive to light. Athough, when extreme care is taken in this operation, it is hardly of any consequence when this is performed, yet in practice it will not be found convenient to *excite* the paper earlier than about a fortnight before its being required for use. The materials for the exciting bath are nitrate of silver, glacial acetic acid, and water. Some operators replace the acetic acid by tartaric acid; but as I cannot perceive the effect of this change except in a diminution of sensitiveness, I have not adopted it. It is of little importance what be the strength of the solution of nitrate of silver; the disadvantages of a weak solution are, that the sheets require to remain in contact with it for a considerable time before the decomposition is effected, and the bath requires oftener renewing; while with a bath which is too strong, time is equally lost in the long-continued washing requisite to enable the paper to keep good for any length of time. The quantity of acetic acid is also of little consequence.

42. In the following bath, I have endeavoured so to adjust the proportion of nitrate of silver, as to avoid as much as possible both the inconveniences mentioned above:—

Nitrate of silver	300 grains.
Glacial acetic acid	2 drachms.
Distilled water	20 ounces.

The nitrate of silver and acetic acid are to be added to the water, and when dissolved, filtered into a clean dish (10), taking care that the bottom of the dish be flat, and that the liquid cover it to the depth of at least half an inch all over; by the side of this, two similar dishes must be placed, each containing distilled water.

43. A sheet of iodized paper is to be taken by one end and gradually lowered, the marked side downwards, on to the exciting solution, taking care that no liquid gets on to the back, and no air-bubbles are enclosed.

It will be necessary for the sheet to remain on this bath from five to ten minutes; but it can generally be known when the operation is completed by the change in appearance, the pink colour entirely disappearing, and the sheet assuming a pure homogeneous straw colour. When this is the case, one corner of it must be raised up by the platinum spatula, lifted out of the dish with rather a quick movement, allowed to drain for about half a minute, and then floated on the surface of the water in the second dish, while another iodized sheet is placed on the nitrate of silver solution; when this has remained on for a sufficient time, it must be in like manner transferred to the dish of distilled water, having removed the previous sheet to the next dish.

44. A third iodized sheet can now be excited, and when this is completed, the one first excited must be rubbed perfectly dry between folds of clean blotting-paper (14), wrapped up in clean paper, and preserved in a portfolio until required for use; and the others can be transferred a dish forward,

as before, taking care that each sheet be washed twice in distilled water, and that at every fourth sheet the dishes of washing water be emptied, and replenished with clean distilled water: this water should not be thrown away, but preserved in a bottle for a subsequent operation (49).

45. The above quantity of the exciting bath will be found quite enough to excite about fifty sheets of the size here employed, or 3000 square inches of paper. After the bulk has been exhausted for this purpose, it should be kept, like the washing waters, for the subsequent operation of developing (49).

Of course these sensitive sheets must be kept in perfect darkness. Generally sufficient attention is not paid to this point. It should be borne in mind, that an amount of white light, quite harmless if the paper were only exposed to its action for a few minutes, will infallibly destroy it if allowed to have access to it for any length of time; therefore, the longer the sheets are required to be kept, the more carefully must the light, even from gas, be excluded; they must likewise be kept away from any fumes or vapour.

46. Experience alone can tell the proper time to expose the sensitive paper to the action of light, in order to obtain the best effects. However, it will be useful to remember that it is almost always possible, however short the time of exposure, to obtain some trace of effect by prolonged development. Varying the time of exposure, within certain limits, makes very little difference on the finished picture; its principal effect being to shorten or prolong the time of development.

Unless the exposure to light has been extremely long (much longer than can take place under the circumstances we are contemplating), nothing will be visible on the sheet after its removal from the instrument, more than there was previous to exposure; the action of the light merely producing a latent impression, which requires to be developed to render it visible.

47. The developing solution in nearly every case consists of an aqueous solution of gallic acid, with the addition, more or less, of a solution of nitrate of silver.

An improvement on the ordinary method of developing with gallic acid, formed the subject of a communication to the Philosophical Magazine for March 1855, where I recommend the employment of a strong alcoholic solution of gallic acid, to be diluted with water when required for use, as being more economical both of time and trouble than the preparation of a great quantity of an aqueous solution for each operation.

48. The solution is thus made: put two ounces of crystallized gallic acid into a dry flask with a narrow neck; over this pour six ounces of good alcohol (60° over proof), and place the flask in hot water until the acid is dissolved, or nearly so. This will not take long, especially if it be well shaken once or twice. Allow it to cool, then add half a drachm of glacial acetic acid, and filter the whole into a stoppered bottle.

49. The developing solution which I employ for one set of sheets, or 180 square inches, is prepared by mixing together ten ounces of the water that has been previously used for washing the excited papers (44), and four drachms of the exhausted exciting bath (45); the mixture is then filtered into a perfectly clean dish, and half a drachm of the above alcoholic solution of gallic acid poured into it. The dish must be shaken about until the greasy appearance has quite gone from the surface; and then the sheets of paper may be laid down on the solution in the ordinary manner with the marked side downwards, taking particular care that none of the solution gets on the back of the paper, or it will cause a stain. Should this happen, either dry it with blotting-paper, or immerse the sheet entirely in the liquid.

50. If the paper has been exposed to a moderate light, the picture will

begin to appear within five minutes of its being laid on the solution, and will be finished in a few hours. It may, however, sometimes be requisite, if the light has been feeble, to prolong the development for a day or more. If the dish be perfectly clean, the developing solution will remain active for the whole of this time, and when used only for a few hours, will be quite clear and colourless, or with the faintest tinge of brown; a darker appearance indicates the presence of dirt. The progress of the development may be watched, by gently raising one corner with the platinum spatula, and lifting the sheet up by the fingers. This should not be done too often, as there is always a risk of producing stains on the surface of the picture. I prefer allowing the development to go on until the black is rather more intense than ultimately required, as it is generally toned down in the fixing bath.

51. As soon as the picture is judged to be sufficiently intense, it must be removed from the gallo-nitrate, and laid on a dish of water (not necessarily distilled). In this state it may remain until the final operation of fixing, which need not be performed immediately, if inconvenient. After being washed once or twice, and dried between clean blotting-paper, the picture will remain unharmed for weeks, if kept in a dark place.

52. The *fixing bath* is composed of a saturated solution of hyposulphite of soda diluted with its own bulk of water. Into this the sheets are to be completely immersed, until the whole of the yellow iodide of silver has been dissolved out. This operation need not be performed by yellow light; daylight is much better for showing whether the picture be entirely fixed. This will take from a quarter of an hour to two hours, according to the time the bath has been in use.

It will be well not to put too many sheets into the bath at once, in order to avoid the necessity of turning them over to allow the liquid to penetrate every part.

When fixed, the sheet, if held up between the light and the eye, will present a pure transparent appearance in the white parts.

The fixing bath gradually becomes less and less active by use, and then its action is very energetic on the dark parts of the picture, attacking and dissolving them equally with the unchanged iodide. When this is the case it should be put on one side (not thrown away), and a fresh bath made.

53. After removal from the fixing bath, the sheets must be well-washed. In this operation, the effect depends more upon the quantity of water used than upon the duration of the immersion. When practicable, it is a good plan to allow water from a tap to flow over the sheets for a minute or two, and having thus got rid of the hyposulphite of soda from the surface, to allow them to soak for about ten minutes in a large dish of hot water.

54. They are then to be dried by hanging up by a crooked pin, as after iodizing. When dry, they will present a very rough and granular appearance in the transparent parts; this is removed by melting the wax, either before a fire, or, what is far better, by placing them between blotting-paper, and passing a warm iron over them; by this means the white parts will recover their original transparency.

55. The picture, arrived at this stage, may be considered finished, as far as is requisite for the purposes of measurement and registration; sometimes, however, it may be necessary to multiply copies, for the purpose of transmitting to other Meteorological Observatories facsimiles of the records, or at least of those containing any remarkable phenomena. I will therefore now detail the method of printing photographic positives from these negatives, premising that the process does not differ materially from that usually adopted.

56. The only extra piece of apparatus required, is a *pressure frame*; which consists essentially of a stout piece of plate glass in a frame, with an arrangement for screwing a flat board, the size of the glass, tight against it. Though apparently very simple, some care is required, when the frame is a large one, in arranging the screw and board at the back, so as to obtain an equal pressure all over the surface; unless this is done, the glass will be very liable to break. The pressure frames supplied to us by Messrs. Newman and Murray, 122 Regent Street, are unexceptionable in this respect. The board should of course be well-padded with velvet, and the lateral dimensions of the glass should be the same as those of the gutta-percha dishes (8).

57. The extra chemicals required for this process are chloride of sodium and chloride of gold. Generally speaking, for the former, common table-salt will be found quite pure enough; but as the quantity required is but small, it will perhaps be found better to obtain some of the recrystallized salt along with the other chemicals.

The chloride of gold is merely required for an artistic effect. Many persons object to the reddish-brown appearance of ordinary photographic positives; the addition of a little chloride of gold to the fixing bath converts this into a rich brown or black; the trifling quantity required removes any objection to its use on the score of expense.

58. I prefer using the same kind of paper for positives as for negatives (20). Messrs. Canson manufacture a thicker paper, which is generally called positive paper, but I think the thin is far preferable; the surface is smoother, and the various solutions penetrate much better.

59. The first operation which the paper has to undergo is *salting*; the bath for this purpose consists of

Chloride of sodium..................100 grains.
Distilled water .... 40 ounces.

Filter this into a clean dish, and completely immerse the sheets, marked as directed (27). This is best done by laying them gently on the surface of the liquid, and then pressing them under by passing a glass rod over them; as many sheets as the dish will hold may be thus immersed one after the other. Allow them to soak for about ten minutes, then lift and turn them over in a body; afterwards they may be hung up to dry (38), commencing with the sheet which was first put in. When dry, they may be taken down and put aside for use at any future time. The sheets in drying generally curl up very much; it will therefore be found convenient in the next process, if the salted sheets, before being put away, have been allowed to remain in the pressure frame, screwed tight, for about twenty-four hours. This makes them perfectly flat.

60. The exciting bath is composed of

Nitrate of silver.................... 150 grains.
Distilled water .... 10 ounces.

After filtering, pour the solution into a clean dish; and then lay the sheets, salted as above, on the surface, face downwards, gently breathing on the back, if it be necessary, to counteract the tendency to curl up; let them remain on this bath for about ten minutes, and then hang up to dry (38).

61. This exciting bath will serve for nearly one hundred sheets; it will then be better to put it on one side (64), and make a new bath. It is not advisable to excite more positive sheets than will be likely to be required in the course of a week, for they gradually turn brown by keeping, even in the dark, and lose sensitiveness. They will, however, keep much better if pressed tight in the pressure frame, and thus protected from the air.

62. When a positive is to be printed from a negative, let the glass of the pressure frame be perfectly cleaned and freed from dust on both sides, then lay the negative on it, with its back to the glass. On it place a sheet of positive paper, with its sensitive side down. Then, having placed over, as a pad, several sheets of blotting-paper, screw the back down with sufficient force to press the two sheets into close contact, but of course not so as to endanger the glass. Now place the frame in the sun, so that the light can fall perpendicularly on the glass, and allow it to remain there until it is judged to have been exposed long enough.

63. No rule can be laid down for the proper time of exposure; it will depend upon the quality of the light and intensity of the negative; some pictures being completed in a few minutes, others requiring upwards of half an hour. The printing should always go on until the picture is several shades darker than ultimately required. A very little experience will enable the operator to judge so well of the quality of the light, as hardly ever to have a failure. If the two sheets of paper be stuck together in two or three places at the edges with small pieces of gummed paper, the frame can be removed to the dark room, and the progress of the sheets examined; but this is always attended with some danger, for unless they are replaced without having been shifted one from the other, there will be a double image.

64. As soon as the picture is considered to be printed sufficiently deep, it has to be fixed.

The fixing bath consists of

Saturated solution of hyposulphite of soda	10 ounces.
Water	30 ounces.

This bath will be found to fix the pictures perfectly, but they will generally be of a reddish tint; if it be thought desirable to obtain the pictures of some shade of dark brown or black, it will be necessary to employ a bath made as follows:—

Saturated solution of hyposulphite of soda	10 ounces.
Water	10 ounces.
Exhausted positive exciting solution (61)	10 ounces.

Mix these together, and then add the following:—

Water	10 ounces.
Chloride of gold	20 grains.

taking care in mixing to pour the solution of gold into the solution of hyposulphite, and not the latter into the former, or another decomposition will be produced.

Pour this mixture into a dish, and lay the positive carefully on it, face downwards. As soon as it is thoroughly damp (which may be known by its becoming perfectly flat after having curled up), immerse it totally in the liquid.

65. The pictures should not be too crowded in the bath, as they are very apt to become irregularly coloured in places where the hyposulphite has not had free access during the whole of the time. When first put in, the colour will change to a light brown, and in the course of some time, varying from ten minutes to two or three hours, it will pass through the different shades of brown to black and purple, gradually fading in intensity during the time. It will be necessary to allow the picture to remain in this bath for ten minutes *at least*, in order that it may be perfectly fixed. After this time, its stay

need only be prolonged until it has become of the desired tone and colour; always remembering, that during the subsequent operation of drying, &c. it will become of a somewhat darker tint than when taken out of the fixing bath.

66. On removal from this bath, the pictures must be allowed to soak in a large quantity of cold water for ten or twelve hours. There must not be very many in the dish at a time, and the water must be changed at least three times during that interval; they must then have boiling water poured over them (of course in a *porcelain* dish) two or three times, and lastly be pressed dry between sheets of clean blotting-paper (14) (these may be used several times, if dried), and then allowed to dry spontaneously in the air. When the pressure frame is not in use, a pile of these finished positives may be put in, and kept tightly screwed up all night; by this means they will be rendered perfectly flat and smooth.

67. The picture is now complete. It must be borne in mind, however, that the light and shade are reversed by this operation, the track of the luminous image along the paper being represented by a *white* instead of by a *black* band, as in the original negative. Should it be desired to produce exact facsimiles of the negatives, it can be done by employing one of these positives as a negative, and printing other positives from it; in this way, the light and shade, having been twice reversed, will be the same as in the original negative.

68. In some cases it may happen that, owing to a partial failure of gas, or imperfection in the sensitive sheet, an image may be so faint as to render it impossible to print a distinct positive. The gap that this would produce in a set of pictures may be obviated, and with very slight sacrifice of accuracy, by forming an artificial or *secondary* negative in the following manner:—

69. Print a copy on positive paper, of any intensity which will show the most distinct impression; then without fixing, and with a pair of sharp scissors, accurately and carefully cut out the part corresponding to the impressed portion of the negative. Expose this piece to the light until it has become perfectly opake, and then it can either be cemented over the imperfect original sheet, or on a clean sheet of paper, and used as an ordinary negative.

It is astonishing what accuracy and quickness in cutting out even the most intricate pictures, may be obtained with a little practice; the error of the scissors is generally within the error of measurement.

Supplementary Notes to the above description, embodying some slight changes in the process made at Kew. By C. Chambers.

1. After reaching the stage described in art. 28, a pile of paper is to be made up, in which eight plain (unwaxed) sheets alternate with one waxed sheet, and in this state is to be placed between hot plates and subjected to high pressure for several hours, when the mass of paper will be found to be completely permeated by the wax. The operation is to be repeated four or five times, and the sheets, being separated after cooling, will be ready for iodizing.

The operation of pressing is best accomplished with the paper *not* folded, and of the full size as received from the maker, so that the edges which retain superfluous wax may be cut off and rejected, and the sheets then cut into pieces of the required shape. Piles half an inch in thickness may be done at once in this way, and using several series of hot plates, any quantity of paper may be put through the press in one night. The hot-pressing apparatus is used by the paper-makers, and by some of the wholesale stationers.

2. The iodizing bath, which should be kept in the dark when not in use, consists of—

Iodide of potassium......	$582\frac{1}{2}$ grains.
Bromide of potassium....	$417\frac{1}{2}$ grains.
Distilled water	40 ozs.
Iodine—sufficient to give the solution a decidedly red tinge.	

With every fresh batch of paper, a small quantity of iodine should be added to restore the red tone of the bath.

The paper is to be hung up to dry in a dark cupboard, and, when dry, it should be of a light reddish-brown colour; if a deep red or purple, it will want sensitiveness; if nearly white, it will want keeping properties, and will become discoloured during development.

3. The exciting bath contains,—

Nitrate of silver	750 grs.
Distilled water	30 ozs.
Acetic acid..............................	3 drms.

A strong solution of nitrate of silver (100 grs. to 1 oz. of water) is kept in a separate bottle for replenishing the exciting bath, which loses by use both in quantity and strength. 2 drms. of this solution with $\frac{1}{4}$ drm. of acetic acid, is added after exciting every three sheets (300 square inches) of paper. The addition of acetic acid prevents discoloration during development, but at the same time slightly diminishes the sensitiveness, and, if added in excess, the intensity of the image is much weakened. When the bath is more than a fortnight old, it is necessary to filter before using. With a weak and old exciting bath the iodide of silver is apt to fall from the sheet in flakes while in the bath, and the portions of the sheet so deprived of silver are no longer sensitive to light: however, there need be no fear of this occurring while the strength of the bath is maintained as above directed. The same exciting solution has been used as long as three months with satisfactory results (1000 square inches of paper being sensitized weekly).

4. (Art. 44.) Instead of drying the sheets between blotting-paper, it has been found to give cleaner and more uniform pictures to hang them up to dry in a dark cupboard; about an inch is cut off each end of the sheet and rejected where the fingers have touched it, and where the fluid has accumulated in dripping.

5. It is very desirable that the exciting and fixing operations should be performed at different times; for if, after fixing, the hands have not been carefully washed, the least remnant of fixing solution left upon the fingers is communicated to the edge and dispersed over the moist surface of the newly sensitized sheet, producing a stain which appears on developing. If a series of black spots, proceeding from one corner of the sheet, show themselves while developing, the cause should probably be looked for in the exciting operation—a drop of the solution accidentally got on the upper side of the floating sheet having trickled down when the sheet was held vertically: when this occurs, it is better (instead of merely floating) to immerse the sheet in the two washing dishes (see art. 43).

6. A sheet of plate-glass, 20 inches by 18 inches, ground at the edges to prevent the solution from flowing off, is used for developing. This was proposed by Mr. Welsh, and it is found to answer extremely well: it rests upon

a wooden cross-piece which fits into a large earthenware dish, and is capable of being roughly levelled by means of screws which support the dish.

It is raised about an inch above the bottom of the dish. A solution consisting of—

Distilled water	8 ozs.
Acetic acid........	1 drm.
Old exciting bath	4 drms. (or 1 drm. of solution of nitrate of silver 100 grs. to 1 oz.)
Gallic acid solution	$1\frac{1}{2}$ drm. (see art. 48)

is poured upon the plate, and the exposed sheets floated side by side upon it. The time required for this operation varies from two hours in summer to six or eight hours in winter.

Note.—In dull weather, the sensitive paper above described may be used with advantage for printing copies of the curves—requiring an exposure of only a few seconds to diffused daylight.

Section IV. On the Method of ascertaining the Instrumental Coefficients, tabulating from the Curves, etc.

1. *Declination Magnetograph.*

In this instrument the distance between the centre of the mirror and the registering cylinder is 6·5 feet, and consequently a change in the position of the dot of light on the sensitive paper, equal to one inch, denotes a change of 22′·18 in the position of the magnet.

The mirrors are so arranged that the moveable dot is north of the fixed dot on the cylinder (see Plate 3. fig. 1); an increase of declination therefore will bring the two dots nearer together, while a decrease of declination will have the opposite effect.

Should the suspension thread be without torsion altogether, or should its torsion remain constant, the same distance between the two dots of light will always denote the same absolute declination; so that if by any means we know the absolute declination corresponding to a given distance between the dots, we shall be able to tell what it is for any other distance, or, in fact, for any moment of time.

The comparability with one another of the various tracings afforded by the instrument, depends on the constancy of the torsion; should this vary, the curves are no longer absolutely comparable. Great attention should therefore be paid to secure, if not an entire absence of torsion, at least a constancy in the little that remains.

The thread should be well freed from torsion when the magnet is suspended: by slightly rubbing it with bees-wax, or by some other similar process, it should be rendered less susceptible to hygrometric influences, and a dish of chloride of calcium should be kept under the glass shade to absorb all moisture. When the magnet is in perfect adjustment, there can be no objection to seal the shade to the marble slab all round with bees-wax, at least if an ordinary loosely fitting shade be used.

Besides all this, it is necessary to make at least every month at some spot free from the influence of iron, observations of absolute declination, noting the precise moment at which each observation is made. The distance between the two dots of light, that is to say between the curve and the base-line of the declination magnetograph, at the moments of observation, wil afford us corrections, which, when applied to our monthly absolute determinations, should bring them all to the same value: in other words, the self-recording magnetograph affords us the means of eliminating the changes that are constantly taking place in the value of the magnetic declination. Should, however, the torsion of the suspension thread of the declination magnetograph have become changed to any extent, our corrected monthly determinations will no longer have the same value.

We are thus presented with a test, by means of which we may ascertain whether change of torsion in the suspension thread, or some other circumstance, such as the change in position of some neighbouring mass of iron, has affected our magnetograph. The following results show that the magnetograph herein described has stood this test in a very satisfactory manner:—

Time of observation of absolute declination.	Declination reduced by magnetograph to Jan. 1858.
	° ′ ″
1858 January	21 56 27
February	21 54 47
March	21 56 2
April	21 56 59
May	21 56 33
August	21 55 38
September	21 57 1
October	21 55 4
1859 October	21 57 7
November	21 56 38
December	21 54 53

Before concluding this part of the subject, I may remark that the magnetographs are merely intended to serve as differential instruments; so that, in addition to their employment, absolute values of the magnetic elements require to be taken from time to time. On this account also, although it is very desirable to have, if possible, no torsion in the thread of the declination magnetograph, and no iron in its neighbourhood, yet the value of the result does not depend so much on the entire absence of these sources of error as in the constancy of the effects which they produce. The greatest caution should therefore be exercised in excluding any hygrometric influence which might change the torsion, and the greatest pains taken to prevent any *shifting* of iron in the neighbourhood of the instruments.

2. *Horizontal-force Magnetograph.*

We have in this case two things to determine, viz. the temperature correction, and the value of one inch on the cylinder in parts of force. With regard to the first of these, the most trustworthy method is to make the observations themselves determine their own temperature correction by means of comparing together two periods, for which the average temperature is different, while the average horizontal force is known to be the same for both. It is, however, advisable that the temperature correction of the horizontal-force magnet should be well determined in the ordinary manner before mounting it. With regard to the scale coefficient, or value of 1 inch in parts of force, it may be well to exhibit in detail the process by which the scale coefficient of the present horizontal-force magnetograph has been determined.

There are two methods by which the scale coefficient is determined. In the first of these, let v denote the angle which the plane of the upper extremities of the wire makes with that of the lower; δv the change, in parts of radius, which is occasioned on v by the moveable dot traversing the sensitive paper one inch; k the scale coefficient, or value of one inch in parts of force; then $k=\cot v\,\delta v$.

By this formula, k, or the scale coefficient, may be determined when v is known. Let us determine v accurately when the magnet is mounted, that is, let us find accurately the angle which the plane of the upper extremities of the wire makes with that of the lower for a certain distance between the fixed and the moveable dot of light upon the cylinder, then we can always find the value of v. Loss of magnetism in the magnet may have widened the distance between the dots on the cylinder since we first determined v*, but knowing the angular value of one inch we can make allowance for this, and thereby determine the present value of v, which will be somewhat less than the first. The loss of magnetism may even have obliged us to turn the torsion circle, in order to bring the dots of light nearer to one another, and of course an accurate account must be taken of this, and allowance made for it in calculating for the future the values of v.

Taking these circumstances into account, viz. the amount of change of the torsion circle, and the distance between the dots, v may always be determined, and, consequently, by the above formula, the scale coefficient may be known.

But as there is some doubt of the rigorous truth of the conditions which the above formula assumes, another method of determining the scale coefficient has been proposed which does not seem open to any such objection.

Let a deflection bar be arranged as in Plate 3. fig. 4 A, 4 a, so as to support a magnet horizontally placed, with its axis in the magnetic meridian, and so that if prolonged it would pass through the centre of the bifilar magnet.

Let the centre of the two magnets be at the distance r from one another. The presence of the deflecting magnet will of course have changed the position of the moveable dot upon the cylinder. Bring the bifilar magnet speedily to rest, and allow the deflecting magnet to remain in its position for about five minutes: this time will sufficiently enable us to procure a photographic impression of the position of the bifilar magnet when deflected; and having its position before and after, we shall thus be enabled to estimate the amount of deflection. Let this be n inches.

Take the same deflecting magnet and place it in a similar position with respect to the declination magnet, and also at the distance r. Here it is obvious that the axis of the deflecting magnet is at right angles to the magnetic meridian. Determine photographically, as before, the angle of deflection which it has caused; let this be u; then k, or the value of one inch in parts of force for the bifilar magnetograph $=\frac{\tan u}{n}$.

Example. On April 30, 1858, the deflecting magnet having been applied as above to the bifilar magnetograph, the deflection produced was $=2\cdot887$ in.

The same magnet being applied in a similar manner, and at the same distance, to the declination magnet, the deflection was $=3\cdot560$ inches $=78'\ 58''$.

Hence $$k=\frac{\tan 78'\ 58''}{2\cdot887}=\cdot00796.$$

A similar observation having been performed at the distances 2·5 and 3·0 feet, we find as a mean result on that date,

$$k=\cdot00800.$$

* In the declination magnetograph a decrease of distance between the dots denotes an increase of westerly declination, while in the bifilar and vertical-force magnetographs it denotes an increase of horizontal and vertical force respectively.

On December 2, 1859, a similar set of observations gave

$$k = \cdot 01004.$$

These may be taken as the correct values of k at their respective dates, but we wish to obtain the values of k for intermediate dates. In order to do this, let us make use of the other formula,

$$k = \cot v \, \delta v.$$

On April 30, 1858, v was nearly $= 43^\circ\ 13'$; hence

$$k = \cot 43^\circ\ 13' \times \frac{1}{117\cdot 24} = \cdot 009078.$$

On December 2, 1859, $v = 35^\circ\ 56'$; hence

$$k = \cot 35^\circ\ 56' \times \frac{1}{117\cdot 24} = \cdot 011769.$$

By the first or more correct formula we find the change that had taken place in the value of k between the two dates to be $\cdot 00204$, while by the latter formula the change is $\cdot 002691$. We cannot go far wrong in supposing that the real change upon k is equal to that given by the formula ($k = \cot v \, \delta v$) multiplied by the fraction $\frac{\cdot 00204}{\cdot 002691}$. Hence to find the real value of k for any value of v, we have

$$k = \frac{\cdot 00204}{\cdot 002691} \{\cot v dv - \cdot 009078\} + \cdot 00800.$$

In these instruments it is of great importance to have magnets which lose their magnetism very slowly; for it is the loss of magnetism, rather than any other cause, which renders it necessary to turn the torsion circle, and occasions changes in the value of the scale coefficient. In connexion with this magnetograph, it is necessary to make frequent observations of absolute horizontal force, noting the precise times at which the observations are made. Such observations will serve to eliminate from the results of the horizontal-force magnetograph those changes which are occasioned by loss of magnetism and stretching of the suspension thread. It is particularly desirable to make absolute observations immediately before and after turning the torsion circle.

3. *Vertical-force Magnetograph.*

The temperature correction of this instrument, if fitted with a slip of brass, as in the present instance, will have to be determined by the observations themselves. It is well, however, as a measure of precaution, to determine the temperature coefficient of the magnet before it is mounted.

With regard to the value of one inch in parts of force, there are two methods by which this may be determined, viz. the method of vibrations, and that of deflections.

With respect to the former of these—

Let T denote the time of vibration of the magnet in a vertical plane;

T′ the time of vibration of the magnet in a horizontal plane*;

Θ the magnetic dip;

Y the vertical component of the earth's force;

which suppose to become $Y + \delta Y$, occasioning a change in the angular position of the magnet represented by $\delta\epsilon$; then it may be shown that

$$\frac{\delta Y}{Y} = \frac{T'^2}{T^2} \cot \Theta \delta\epsilon.$$

* Suspended so as to have the same moment of inertia which it has in the vertical plane.

Again, since the normal to the mirror is inclined at an angle of 15° to the incident ray, and since the sensitive cylinder is 5·965 feet, or 71·58 inches distant from the mirror, it may be shown that the vertical space of one inch traversed by the luminous dot upon the cylinder, represents an angular change in the position of the magnet

$$=\frac{1}{143{\cdot}16\times\cos 15^\circ};$$

hence the value of 1 inch in parts of force

$$=\frac{T'^2}{T^2}\,\frac{\cot\Theta}{143{\cdot}16\cos 15^\circ}.$$

The second method, by which the value of one inch in parts of force may be determined, is that of deflections. Let a suitable apparatus (see Plate 3. figs. 5A, $5a$) be contrived, by means of which a deflection magnet, m, may be placed vertically with its centre at a given distance, r, from that of the vertical-force magnet and in continuation of the magnetic axis of the latter magnet, when horizontal. Let the change of position of the luminous dot upon the cylinder be registered photographically as before; let this be $=n$ inches.

Let the deflecting magnet be now placed with its centre at the distance r from that of the declination magnet, and in continuation of the magnetic axis of the latter magnet; also let the magnetic axis of the deflecting magnet be perpendicular to the magnetic meridian; and, finally, let the angle through which the declination magnet is deflected be determined photographically. Call this angle u; then it may be shown that the value of one inch in parts of force for the vertical-force magnet is found from the following expression:—

$$\text{Value of one inch}=\frac{\tan u}{n\tan\Theta}.$$

By the method of vibrations the value of one inch was determined on February 27th, 1858, to be =·00221 in parts of force, while by the method of deflections (mean of three distances) its value was found to be =·00211 in parts of force. There is thus a very satisfactory agreement between the results of the two processes.

On April 18th, 1860, the value of one inch was determined by the method of deflections to be =·00249 in parts of force. There is thus a change =·00038 which has taken place in the value of one inch during the course of about two years. This has no doubt been occasioned by loss of magnetism of the magnet widening the distance between the dots and rendering it necessary to alter the balance of the magnet by means of the horizontal screw from time to time.

A proper method of interpolation will enable us to determine with sufficient accuracy the value of 1 inch in parts of force for any period between February 27th, 1858, and April 18th, 1860.

It is perhaps a safe rule to determine the value of the scale coefficients of bifilar and vertical-force magnetographs,by the method of deflections, once a year.

Monthly observations of dip are made at Kew, which, combined with the monthly determinations of absolute horizontal force, will enable us to determine the absolute vertical force, and thus to eliminate from the vertical-force curves the changes that have been occasioned by loss of magnetism from time to time.

Method of tabulating from the curves.—By pushing the dots of light forward a little, two days' curves are recorded on each sheet of sensitive paper. These sheets are therefore only changed every second day. This change is made a little after 10 A.M., and the time occupied in making it is about ten minutes, while that occupied in pushing forward the dots is only about three minutes. There is thus every day a loss of ten and of three minutes alternately, so that the curves never record precisely the whole of the twenty-four hours, but generally something less by a few minutes. The precise moment (Kew mean time) of stopping the pendulum and of setting it going again is noted, so that the length of time for which any curve is a record is known and is attached to the curve in writing. (See curves appended to this Report, Plate 5.)

The instrument for tabulating from the curves is represented in Plate 3. fig. 3 A : *ab* is a time-scale commencing and ending with 22^h. This scale is moveable round *a* as a centre, and the centre *a* is also moveable in a horizontal direction. Part of the instrument, *d f g*, is moveable in a vertical direction by means of *h*, the head of a pinion which works into the rack *i*; *d* serves as a vernier for the scale *e*. The piece *c d e f g* is moveable in a horizontal direction by means of a slide which fits into the slot *k l*; *f* and *g* are two tubes through which the eye looks at lines on a piece of glass (exhibited separately at full size in fig. 3 *a*). These are two sets of double lines which are etched on glass, the sets being exactly two inches apart. The distance between the tubes *f* and *g* is also two inches, so that when the upper pair of lines is placed under *f*, the lower pair is under *g*. The glass is firmly attached in this position to the moveable piece *d f g*, so that the double lines remain exactly under the tubes in whatever manner *d f g* is moved. The breadth between the two lines (which together constitute a double line) on the piece of glass is a little greater than the breadth of the curve or zero-line on the photographic paper.

In order to measure the distance between the curve and zero-line, the photographic paper is set between two pieces of plate-glass, and so adjusted, that when the tube *g* is set over the zero-line, it may continue to be approximately over it in any part of its horizontal range.

Suppose now that *c d e f g* is at the extreme left, the vertical line of the piece of glass lying along the commencement of the curve and that of the zero-line. Set the time-scale *ab* so that the edge of the index *e* may touch that hour on the time-scale which corresponds to the commencement of the curve. Adjust the vertical height of *b*, the extremity of the time-scale, so that when *c d e f g* is carried to the other or right-hand extremity of the curve, the index *c* may touch that division of the time-scale which corresponds to the termination of the curve. Were the same length of base-line always to denote the same space of time, there would be no need of altering the inclination of *a b*; but the rate of the clock may vary a little, or the paper may fit more or less loosely to the cylinder, so that an inch of the base-line will not always denote precisely the same space of time. Having thus adjusted the time-scale, in order to find the distance between the base-line and the curve for any hour, set the index *c* to the required time, move the pinion head *h* until the upper pair of etched lines at *f* are over the curve-line, and read off the height on the scale *e* by means of the vernier *d*. Next move the pinion head *h* until the lower pair of etched lines at *g* are over the base-line, and read off by means of the vernier as before. The difference between the readings for the curve and the base-line *plus* two inches, gives the distance between these lines.

In case any shifting should take place, it is best to read the curve and its corresponding base-line consecutively, instead of reading first a number o points of the curve together, and then the corresponding points of the base-line together also. Occasionally the presence of iron for a short time may cause an abrupt rise and fall of small size in the curve, the one motion being due to the approach of the iron, and the other to its removal. These must be taken into account in tabulating from the curves. An instance of this occurs in the curves appended to this Report.

Section V. Improvements in the Construction of a Set of Self-recording Magnetographs since made.

Magnetographs very similar to those here described have been lately set up in a house constructed to receive them about 70 yards from the Kew Observatory.

The following improvements were made in their construction:—

1. Instead of one large glass shade standing upon the marble slab, each magnetograph has a gun-metal cylinder, which stands upon the slab, and is surmounted by a glass shade of comparatively small size. An opening is cut in the side of the cylinder, in which there is inserted a piece of perfectly plane glass; this glass covers that space which in the old arrangement would have been occupied by the two round holes already described. The lens is apart from the cylinder, and has an adjustment to admit of its distance from the mirror being altered if necessary.

This arrangement permits the shades to be removed without disturbing the lenses. It also renders the working of the instrument less liable to interruption in case of any accident happening to the shade.

There is also a tube inserted through the marble, which may be connected with an air-pump and the interior of the cylinder and shade exhausted, if this be thought necessary.

2. The second improvement consists in having reading telescopes with ivory or other scales mounted on pillars, and so placed that the light from the divisions of the scale falling upon the moveable mirror attached to the magnet is reflected into the telescope. In consequence of this, the motion of the mirror will cause an apparent motion of the scale in the field of view of the telescope. The position of the magnet will therefore be known by observing what division of the scale is in contact with the vertical wire of the telescope.

We may thus combine the photographic record with eye observations. The advantage of the latter is that we see what is taking place at the very moment of its occurrence, whereas we only obtain the photographic record a couple of days after the changes to which it relates have happened.

Should a disturbance take place, we are thus not only made aware of it at the time of its occurrence, but we may, by having a telescope scale of greater range than the recording cylinder, obtain eye observations, when owing to excessive disturbance the dot of light has altogether left the sensitive paper.

Report on the Theory of Numbers.—Part I.

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1. The 'Disquisitiones Arithmeticæ' of Karl Friedrich Gauss (Lipsiæ, 1801) and the 'Théorie des Nombres' of Adrien Marie Legendre (Paris, 1830, ed. 3) are still the classical works on the Theory of Numbers. Nevertheless, the actual state of this part of mathematical analysis is but

imperfectly represented in those celebrated treatises. The arithmetical memoirs of Gauss himself, subsequent to the publication of the 'Disquisitiones Arithmeticæ;' those of Cauchy, Jacobi, Lejeune Dirichlet, Eisenstein, Poinsot, and, among still living mathematicians, of MM. Kummer, Kronecker, and Hermite, have served to simplify as well as to extend the science. From the labours of these and other eminent writers, the Theory of Numbers has acquired a great and increasing claim to the attention of mathematicians. It is equally remarkable for the number and importance of its results, for the precision and rigorousness of its demonstrations, for the variety of its methods, for the intimate relations between truths apparently isolated which it sometimes discloses, and for the numerous applications of which it is susceptible in other parts of analysis. "The higher arithmetic," observes Gauss*, confessedly the great master of the science, "presents us with an inexhaustible store of interesting truths,—of truths, too, which are not isolated, but stand in a close internal connexion, and between which, as our knowledge increases, we are continually discovering new and sometimes wholly unexpected ties. A great part of its theories derives an additional charm from the peculiarity that important propositions, with the impress of simplicity upon them, are often easily discoverable by induction, and yet are of so profound a character that we cannot find their demonstration till after many vain attempts; and even then, when we do succeed, it is often by some tedious and artificial process, while the simpler methods may long remain concealed."

2. It is the object of the present report to exhibit an outline of the results of these later investigations, and to trace (so far as is possible) their connexion with one another and with earlier researches. An attempt will also occasionally be made to point out the *lacunæ* which still exist in the arithmetical theories that come before us; and to indicate those regions of inquiry in which there seems most hope of accessions to our present knowledge. In order, however, to render this report intelligible to persons who have not occupied themselves specially with the Theory of Numbers, it will be occasionally necessary to introduce a brief and summary indication of principles and results which are to be found in the works of Gauss and Legendre. It is hardly necessary to add that we must confine ourselves to what we may term the great highways of the science; and that we must wholly pass by many outlying researches of great interest and importance, as we propose rather to exhibit in a clear light the most fundamental and indispensable theories, than to embarrass the treatment of a subject, already sufficiently complex, with a multitude of details, which, however important in themselves, are not essential to the comprehension of the whole.

3. There are two principal branches of the higher arithmetic:—the Theory of Congruences, and the Theory of Homogeneous Forms. The first of these theories relates to the solution of indeterminate equations, of the form

$$a_n x^n + a_{n-1} x^{n-1} + \dots + a_1 x + a_0 = \mathrm{P}y,$$

in which $a_n\, a_{n-1} \dots a_1\, a_0$ and P are given integral numbers, and x and y are numbers which it is required to determine. The second relates to the solution of indeterminate equations of the form

$$\mathrm{F}(x_1\, x_2 \dots x_m) = \mathrm{M},$$

in which M denotes a given integral number, and F a homogeneous function

* Preface to Eisenstein's 'Mathematische Abhandlungen,' Berlin, 1847.

of any order with integral coefficients. In this general point of view, these two theories are hardly more distinct from one another than are in algebra the two theories to which they respectively correspond,—the Theory of Equations, and that of Homogeneous Functions; and it might, at first sight, appear as if there was not sufficient foundation for the distinction. But, in the present state of our knowledge, the methods applicable to, and the researches suggested by these two problems, are sufficiently distinct to justify their separation from one another. We shall therefore classify the researches we have to consider here under these two heads; those miscellaneous investigations, which do not properly come under either of them, we shall place in a third division by themselves.

(A) *Theory of Congruences.*

4. *Definition of a Congruence.*—If the difference between A and B be divisible by a number P, A is said to be *congruous to* B *for the modulus* P; so that, in particular, if A be divisible by P, A is *congruous to zero for the modulus* P. The symbolic expressions of these congruences are respectively

$$A \equiv B, \text{ mod } P,$$
$$A \equiv 0, \text{ mod } P.$$

Thus $7 \equiv 2$, mod 5; $13 \equiv -3$, mod 8.

It will be seen that the definition of a congruence involves only one of the most elementary arithmetical conceptions,—that of the divisibility of one number by another. But it expresses that conception in a form so suggestive of analogies with other parts of analysis, so easily available in calculation, and so fertile in new results, that its introduction into arithmetic (by Gauss) has proved a most important contribution to the progress of the science. It will be at once evident, from the definition, that congruences possess many of the properties of equations. Thus, congruences in which the modulus is the same may be added to one another; a congruence may be multiplied by any number; each side of it may be raised to any power whatever, and even may be divided by any number prime to the modulus.

5. *Solution of a Congruence.*—If $\phi\ (x)$ denote a rational and integral function of x with integral coefficients (we shall, throughout this report, attach this meaning to the functional symbols F, f, ϕ, &c., except when the contrary is expressly stated); the congruence $\phi\ (x) \equiv 0$, mod P, is said to be solved, when all the integral values of x are assigned which make the left hand number of the congruence divisible by P; *i. e.* which satisfy the indeterminate equation $\phi(x) = Py$. It is evident that if $x=a$ be a solution of the congruence $\phi(x) \equiv 0$, every number included in the formula $x=a+\mu P$ is also a solution of the congruence. But the solutions included in that formula are all congruous to one another and to a. It is proper, therefore, to consider all these congruous solutions as identical, and in speaking of the number of solutions of a congruence to understand the number of sets of incongruous solutions of which it is susceptible. To assign, by a direct method, all the solutions of which a proposed congruence is capable, is the general problem which, in the Theory of Numbers, corresponds to the problem of the solution of numerical equations in ordinary algebra. But the solution of the arithmetical problem is attended with even greater difficulties than that of the algebraical one; and the attention of geometers has been turned with more success to the improvement of the indirect or tentative methods of solution, and to the discovery of criteria of possibility or impossibility for congruential formulæ, than to their direct solution. It is to be observed that, by virtue of a remark already made, the *tentative*

solution of a congruence involves no theoretical difficulty. For if $x=a$ be a solution, every number included in the formula $x=a+\mu P$ is also a solution, and among these numbers there is always one, and only one, comprised within the limits 0 and $P-1$ inclusively. By substituting, therefore, for x all numbers in succession less than the modulus, and rejecting those which do not satisfy the congruence, we shall obtain its complete solution. But the interminable labour attending this operation, notwithstanding all the abbreviations in it suggested by the Calculus of Finite Differences, renders its application impossible, except when the modulus is a low number.

6. *Systems of Residues.*—The set of numbers $0, 1, 2 \ldots . P-1$ (or any set of P numbers respectively congruous for the modulus P to those numbers) is termed a *complete system of residues for the modulus* P. By *a system of residues prime to* P, we are to understand a complete system, from which every residue has been omitted which has any common divisor with P. Thus $1, 5, 7, 11$, or $1, 5, -5, -1$, are the terms of a system of residues prime to 12. The word Residue is employed instead of Remainder, because the word Remainder would suggest the idea of a positive number less than the modulus or divisor; whereas it is frequently convenient to consider residues differing from those positive remainders by any multiples of the modulus whatever.

7. *Linear Congruences.*—The general form of a linear congruence is $ax+b\equiv 0$, mod P; a, b, and P denoting given numbers, and x a number to be determined.

The theory of these congruences may be considered to be complete, both as regards the determination of the solutions or *roots* themselves and of their number. If a be prime to the modulus, there is always one solution, and one only; if a have a common divisor with the modulus which does not also divide b, the congruence is irresoluble; if δ be the greatest common divisor of a and P, and if δ also divide b, the congruence has δ solutions. In every case when the congruence is resoluble, the direct determination of its roots may be made to depend on the solution of a congruence of the form $ax\equiv 1$, mod P, in which a is prime to P. This congruence coincides with the indeterminate equation $ax=1+Py$, methods for the solution of which were known to the ancient Indian geometers*, and have been given in Europe by Bachet de Meziriac† Euler‡, and Lagrange§. The methods of these writers ultimately depend on the conversion of a vulgar fraction into a continued fraction, and in one form or another have passed into every book on algebra. Nor would it have been proper to allude to them here, were it not that they serve to supply us with a clear conception of what we have a right to expect in the solution of an arithmetical problem. In such problems, we cannot expect to express the *quæsita* as (discontinuous) analytical functions of the *data*. Such expressions may indeed, in many cases, be obtained (by the use of the roots of unity or by other methods); but the results of the kind which have hitherto been given, though sometimes of use in calculation, may be said, with few exceptions, to conceal rather than to express the real connexion between the

* See the Arithmetic of Bhascara, cap. xii., and the Algebra of Brahmegupta, cap. i. in Mr. Colebrooke's translation, London, 1817.

† Problèmes plaisans et délectables, qui se font par les nombres. Seconde édition. Par Claude Gaspar Bachet, Sieur de Meziriac, Lyon, 1624. (See props. xv. to xxv.)

‡ Comment. Acad. Petropol. tom. vii. p. 46, or in the Collection of Euler's Arithmetical Memoirs (L. Euleri Commentationes Arithmeticæ Collectæ, Petropoli, 1849), vol. i. p. 2; and in his Elements of Algebra, part ii. cap. 1.

§ Sur la Résolution des Problèmes Indéterminés du seconde degré. Hist. de l' Acad. de Berlin, 1767, p. 165. (See Arts 7, 8, and 29 of the Memoir.) Also in the Additions to Euler's Algebra, sects. i. and iii. (Lyon, an. III.)

numbers required and the numbers given. The arithmetical solution of a problem should consist in prescribing a finite number of purely arithmetical operations (exempt from all tentative processes), by which all the numbers satisfying the conditions of the problem, and those only, are obtained. It is clear that this description exactly applies to the methods on which the solution of linear congruences depends; but, unfortunately, the higher arithmetic presents but few examples of solutions of equal perfection.

8. Besides the older methods for the solution of the equation $ax=1+Py$, others have, in very recent times, been suggested. Of these the following may serve as examples:—

A. In the equation $ax=1+Py$, or the congruence $ax\equiv 1$, mod P, form the residues of the successive powers of a for the modulus P. If a be prime to P, we shall at last arrive at a power which has $+1$ for its remainder or residue. The residue of the power immediately inferior to this power is the value of x in the congruence $ax\equiv 1$, mod P. This solution is evidently an application of Fermat's Theorem*.

B. Let there be P points $A_1\, A_2 \ldots A_P$, arranged at equal distances on the circumference of a circle. Join A_1 to A_{a+1}, A_{a+1} to $A_{2a+1} \ldots$ and so on continually. It can be proved that if a be prime to P, we shall not return again to A_1, until we have passed through every one of the P points, and have formed a polygon of P sides. Let $X_1\, X_2 \ldots X_P$ be the vertices of this polygon, taken in order, and let $A_2=X_{m+1}$; then $x\equiv m$ is the value of x in the congruence $ax\equiv 1$, mod P†.

C. Let an origin and a pair of axes be assumed in a plane, and let all the points be constructed whose coordinates are integral multiples of the linear unit; call these points unit points. Join the origin to the point (a, P). If a be prime to P, no unit point can lie on the joining line, but on each side of the joining line there will be a point lying nearer to it than any other. Let $(\xi_1\, \eta_1)$, $(\xi_2\, \eta_2)$ be the coordinates of these points, and let $\xi_1 : \eta_1 < \xi_2 : \eta_2$; then ξ_1, η_1, and ξ_2, η_2 are the least positive numbers satisfying the equations $a\,\eta_1 - P\xi_1 = 1$, $a\eta_2 - P\xi_2 = -1$.

The late M. Crelle, of Berlin, in the 45th volume of his Journal (p. 299), has given a very useful table, containing the least positive numbers x_1 and x_2 which satisfy the equation $a_1\, x_1 - a_2\, x_2 = 1$, for all values of a_1 up to 120, and for all values of a_2 prime to a_1 and less than it.

9. *Systems of Linear Congruences.*—The theory of these systems is left imperfect in the work of Gauss (see Disq. Arith. art. 37); but, by the aid of a few subsidiary propositions relating to determinants, we may, in every case, obtain directly all possible solutions of any proposed system; and (what is frequently of more importance) we can decide *a priori* whether a given system of linear congruences be resoluble or not, and if it be resoluble we can assign the number of its solutions. The following theorems by which the determination of the number of solutions is, in every case, effected, will sufficiently indicate the nature of these investigations.

Let the proposed system of congruences be represented by

$$(1, 1)\, x_1 + (1, 2)\, x_2 + (1, 3)\, x_3 + \ldots + (1, n)\, x_n \equiv u_1$$

* Binet, sur la Résolution des équations du premier degré en Nombres entiers. (Journal de l'École Polytechnique, cahier xx., p. 289.)

Libri, Mémoires de Mathématique et Physique (Florence, 1829), p. 65–67.

Poinsot, Réflexions sur les Principes Fondamentals de la Théorie des Nombres (Paris, 1845), cap. iii. nos. 19 & 20. For another solution by M. Binet, see Comptes Rendues, xiii., p. 349. See also Cauchy, Comptes Rendues, xii. p. 813.

† Poinsot, Reflexions, &c., cap. iii., nos. 17 and 18.

$$(2, 1)\, x_1 + (2, 2)\, x_2 + (2, 3)\, x_3 + \ldots + (2, n)\, x_n \equiv u_2 \qquad \text{(A).}$$
$$\cdots\cdots\cdots\cdots\cdots$$
$$(n, 1)\, x_1 + (n, 2)\, x_2 + (n, 3)\, x_3 + \ldots + (n, n)\, x_n \equiv u_n;$$

let the modulus be q, and the determinant $\Sigma \pm (1, 1)\,(2, 2)\ldots(n, n) = \mathrm{D}$. If the determinant be prime to the modulus, these congruences will always admit of one, and only one, system of solutions, namely, that supplied by the system of congruences

$$\mathrm{D}x_r \equiv \sum_{k=1}^{k=n} \frac{d\mathrm{D}}{d\,(k, r)}\, u_k.$$

But if D be not prime to q, let $q = p_1^{m_1} . p_2^{m_2} \ldots\ldots$ where p_1, p_2, &c. denote different primes. In order that the proposed system should be resoluble for the modulus q, it must be separately resoluble for each of the modules $p_1^{m_1}$, $p_2^{m_2}$, &c.; and conversely if it be resoluble for each of those modules, and admit P_1 solutions when taken with respect to the modulus $p_1^{m_1}$, P_2 solutions when taken with respect to the modulus $p_2^{m_2}$, and so on, it will be also resoluble for the modulus q, and will admit $\mathrm{P}_1 \times \mathrm{P}_2 \times \mathrm{P}_3 \ldots$ solutions for that modulus. It is, therefore, only necessary to assign the number of solutions of the congruences (A), for a modulus p^m which is the power of a prime. Let I_n be the index of the highest power of p which divides D; and similarly let I_r denote the index of the highest power of p which divides all the minors of D which are of order r; then if $\mathrm{I}_n - \mathrm{I}_{n-1} \leqq m$, the system (A) (if resoluble at all) admits of p^{I_n} solutions; but if $\mathrm{I}_n > m + \mathrm{I}_{n-1}$, it will always be possible, in the series of differences

$$\mathrm{I}_n - \mathrm{I}_{n-1},\ \mathrm{I}_{n-1} - \mathrm{I}_{n-2}, \ldots\ldots$$

to assign a pair of consecutive terms $\mathrm{I}_{r+1} - \mathrm{I}_r$, $\mathrm{I}_r - \mathrm{I}_{r-1}$, satisfying the inequalities

$$\mathrm{I}_{r+1} - \mathrm{I}_r > m \geqq \mathrm{I}_r - \mathrm{I}_{r-1};$$

and then the number of solutions (supposing always that the congruences are resoluble) is expressed by the formula $p^{\mathrm{I}_r + (n-r)m}$.

The analogy of this theory with the corresponding algebraic theory of systems of linear equations is in particular cases very striking. For example, we have in Algebra the theorem

"The system of n linear equations

$$(1, 1)\, x_1 + (1, 2)\, x_2 + (1, 3)\, x_3 + \ldots + (1, n)\, x_n = 0$$
$$(2, 1)\, x_1 + (2, 2)\, x_2 + (2, 3)\, x_1 + \ldots + (2, n)\, x_n = 0$$
$$\cdots\cdots\cdots$$
$$(n, 1)\, x_1 + (n, 2)\, x_2 + (n, 3)\, x_3 + \ldots + (n, n)\, x_n = 0$$

implies either that $\mathrm{D} = \Sigma \pm (1, 1)\ (2, 2) \ldots (n, n) = 0$, or else that $x_1\, x_2 \ldots x_n$ are separately equal to zero."

In the Theory of Numbers we have the corresponding theorem,

"If n linear and homogeneous functions of an equal number of indeterminates be congruous to zero for a prime modulus, either the determinant of the system is congruous to zero for that modulus, or else every one of the indeterminates is separately congruous to zero."

10. *Fermat's Theorem.*—The theory of congruences of the higher orders is so essentially connected with Fermat's Theorem, that it will be proper before proceeding further to introduce a few considerations relating to that celebrated proposition.

It may be considered from two different (though closely connected) points of view, each of which has proved equally fertile in consequences. First, it may be regarded as asserting that, if p be a prime number, and x any number prime to p, the remainder left by the power x^{p-1} when divided by p is unity. It is thus the fundamental proposition in the arithmetical theory of the residues of powers, or, which is the same thing, of binomial congruences. Or, secondly, it may be regarded as asserting that the congruence $x^{p-1} \equiv 1$, mod p, has precisely $p-1$ roots; and that these roots are the terms of a system of residues prime to p. It is in this latter point of view that the theorem is the basis of the general theory of congruences.

We may observe that the demonstrations of Fermat's Theorem point to this twofold aspect.

The proof which is found in most English treatises of Algebra (it is the first of those given by Euler*), and which depends on the property of the binomial or multinomial coefficient, would naturally lead us to regard the Theorem in the first point of view. The same may be said of Euler's second demonstration†, which consists in showing that the index of the lowest power of x in the series $1, x, x^2, x^3$, &c., which leaves unity for its remainder when divided by p, is either $p-1$, or some submultiple of $p-1$; or again of the demonstration of MM. Dirichlet‡, Binet§, and Poinsot‖, which depends on the observation that the terms of a system of residues prime to any modulus, being multiplied by any residue prime to the modulus, still form a system of residues prime to the modulus.

But a remarkable proof of the theorem, in the second expression we have given to it, occurs in a memoir of Lagrange¶. As this proof (though very elementary) has not been copied by subsequent writers, and is consequently but little known, its nature may be indicated here.

Let the product

$$(x+1)(x+2)(x+3)\ldots\ldots(x+p-1)$$

be represented by

$$x^{p-1}+A_1 x^{p-2}+A_2 x^{p-3}+\ldots\ldots A_{p-2}x+A_{p-1},$$

x denoting an absolutely indeterminate quantity. Writing $x+1$ for x, and multiplying by $x+1$, we obtain the identity

$$\begin{aligned}(x+1)^p+A_1(x+1)^{p-1}+A_2(x+1)^{p-2}+\ldots+A_{p-1}(x+1)\\ =(x+p)\left[x^{p-1}+A_1x^{p-2}+A_2x^{p-3}+\ldots+A_{p-2}x+A_{p-1}\right];\end{aligned}$$

whence, by equating the coefficients of like powers of x, we find,

$$A_1=\frac{p(p-1)}{1.2}$$

* Comment. Acad. Petropol. vol. viii. p. 141, or Comment. Arith. vol. i. p. 21. This is the first demonstration of the Theorem discovered, since the time of Fermat. The memoir containing it was presented to the Academy of St. Petersburgh, Aug. 2, 1736.

† Novi Commentarii Petropol. vol. vii. p. 49, or Comment. Arith. vol. i. p. 260. From the point of view in which Fermat presents his theorem, it is not improbable that the demonstration he had found of it was no other than this of Euler's. (See Fermati Opera Mathematica, Tolosæ, 1679, p. 163.) It has been adopted by Gauss in the Disquisitiones, Art. 49.

‡ Crelle's Journal, vol. iii. p. 390.

§ Journal de l'École Polytechnique, Cahier xx. p. 289.

‖ Reflexions sur la Théorie des Nombres, p. 32. But the principle of this demonstration is employed by Gauss in a memoir published in the Comm. Soc. Gotting. vol. xvi. p. 69, to which we shall have again to refer. (See Art. 19 of this Report.)

¶ Démonstration d'un Théoreme nouveau concernant les Nombres Premiers (Nouveaux Mémoires de l'Académie Royale de Berlin, 1771, p. 125). The 'new theorem' is that known as Sir J. Wilson's.

$$2A_2 = \frac{p(p-1)(p-2)}{1.2.3} + \frac{(p-1)(p-2)}{1.2} A_1$$

$$3A_3 = \frac{p(p-1)(p-2)(p-3)}{1.2.3.4} + \frac{(p-1)(p-3)}{1.2.3} A_1 + \frac{(p-2)(p-3)}{1.2} A_2$$

. . . .

$$(p-1)A_{p-1} = 1 + A_1 + A_2 + A_3 + \ldots + A_{p-2}.$$

From these equations we successively infer the congruences $A_1 \equiv 0$, $A_2 \equiv 0$, $A_3 \equiv 0, \ldots A_{p-2} \equiv 0$, and lastly $A_{p-1} \equiv -1$, mod p. We have, therefore, the indeterminate congruence $(x+1)(x+2)(x+3)\ldots(x+p-1) \equiv x^{p-1} - 1$, mod p, which is evidently *identical*, *i. e.* it subsists for all values of x. And since, if $a_1, a_2 \ldots a_{p-1}$ be the terms of any system of residues prime to p, the factors $x-a_1, x-a_2, x-a_3, \ldots x-a_{p-1}$, are one by one congruous to the factors $x+1, x+2, x+3, \ldots x+p-1$ taken in a certain order, the products

$$(x-a_1)(x-a_2)\ldots(x-a_{p-1}) \text{ and } (x+1)(x+2)\ldots(x+p-1)$$

are also identically congruous for the modulus p, so that we may write

$$(x-a_1)(x-a_2)\ldots(x-a_{p-1}) \equiv x^{p-1} - 1, \text{ mod } p.$$

This congruence exhibits in the clearest manner possible what the real nature of the function $x^{p-1}-1$ is when considered with respect to the modulus p, and explains to us why it assumes a value divisible by p, when we assign to x any integral value not divisible by p.

It will be observed that the last of the $p-1$ congruences included in the congruence

$$(x-1)(x-2)(x-3)\ldots\ldots(x-p-1) \equiv x^{p-1}-1, \text{ mod } p$$

(which is a particular case of that last written), namely the congruence

$$1.2.3\ldots p-1 \equiv -1, \text{ mod } p$$

is the symbolic expression of Sir J. Wilson's Theorem.

11. *Lagrange's Limit of the Number of Roots of a Congruence.*—The full development of the consequences of Fermat's Theorem requires the aid of the following proposition, which was first given, in a slightly different form, by Lagrange*.

"If $F(x)$ be a function of x of n dimensions, such that $F(a) \equiv 0$, mod p, then a function of x of $n-1$ dimensions, $F_1(x)$, can always be assigned such that we shall have the identical congruence $F(x) \equiv (x-a) F_1(x)$, mod p."

Hence we may infer that no congruence, of which the modulus is prime, can have more incongruous roots than it has dimensions; and, if a congruence have congruous roots, we obtain a definition of their multiplicity; viz., if $F(x) \equiv (x-a)^r F_1(x)$, mod p, then we may say that $F(x) \equiv 0$, mod p, has r roots congruous to a. We may also observe that this theorem enables us at once to infer Lagrange's indeterminate congruence from the first expression of Fermat's Theorem. For since $x^{p-1}-1$ is $\equiv 0$ for the values $x \equiv 1$, $x \equiv 2, \ldots x \equiv p-1$, we may, by successive applications of the preceding theorem, show that $x^{p-1}-1 \equiv (x-1)(x-2)\ldots\ldots(x-p+1)$, mod p.

12. *Theory of the Residues of Powers.*—The principal elementary theorems relating to the Residues of Powers are the following. They are all due to

* Nouvelle Méthode pour resoudre les Problemes Indéterminés en Nombres entiers. (See Hist. Ac. Berl. 1768, p. 192.) The case of binomial congruences of the form $x^n \equiv 1$ had already been treated by Euler. (See Nov. Comment. Petropol. vol. xviii. p. 85, or Comment. Arith. vol. i. p. 516, art. 28 of the Memoir.)

Euler*, who was the first to demonstrate Fermat's Theorem, and to develope the numerous arithmetical truths connected with it.

I. If e and f be *conjugate* divisors of $p-1$ so that $p-1=ef$; the congruence $x^f \equiv 1$, mod p, always admits of f incongruous roots. Let these roots be denoted by $a_1\, a_2 \ldots a_f$. Then each of the f congruences $x^e \equiv a_r$ admits of e solutions, and the ef roots of these f congruences exhaust completely the $p-1$ residues prime to p. It appears, therefore, that if we raise the residues of p to the power e, they will divide themselves into f groups of e numbers apiece; the e numbers of each group giving, when raised to the power e, the same residue for the modulus p. The numbers $a_1\, a_2 \ldots a_f$, are termed the quadratic, cubic, biquadratic, quintic, &c., residues of p, according as $e=2$, $e=3$, $e=4$, $e=5$, &c., because they are each of them congruous to an e^{th} power (and indeed to an e^{th} power of e different numbers), and because no other number beside them can be congruous to such a power. Thus every uneven prime has $\frac{1}{2}(p-1)$ quadratic, and as many non-quadratic residues; every prime of the form $4n+1$ has $\frac{1}{4}(p-1)$ biquadratic residues, and three times as many non-biquadratic residues, &c.

II. It is readily seen that if the same number x satisfy the two congruences $x^{f_1} \equiv 1$, and $x^{f_2} \equiv 1$, it also satisfies the congruence $x^d \equiv 1$, mod p; where d is the greatest common divisor of f_1 and f_2. If therefore f be the *lowest* index for which the number x satisfies the congruence $x^f \equiv 1$, mod p, f is a divisor of $p-1$; as indeed appears directly from Euler's second demonstration of Fermat's Theorem. Let $\psi\ (f)$ denote the number of numbers less than f and prime to it; then there are always $\psi\,(f)$ roots of the congruence $x^f \equiv 1$, mod p, which cannot satisfy any other congruence of lower index, and similar form. These are called *primitive roots* of the congruence $x^f \equiv 1$, mod p; they are also said to *appertain to the exponent* f. If $f=p-1$, the $\psi(p-1)$ primitive roots of the congruence $x^{p-1} \equiv 1$, mod p, are termed for brevity (though the designation is somewhat improper) the *primitive roots of* p. There are therefore $\psi\ (p-1)$ primitive roots of p.

13. *Primitive Roots.*—The problem of the direct determination of the primitive roots of a prime number is one of the "cruces" of the Theory of Numbers. Euler, who first observed the peculiarity of these numbers, has yet left us no rigorous proof of their existence†; though assuming their existence he succeeded in accurately determining their number. The defect in his demonstration was first supplied by Gauss‡, who has also proposed an indirect method for finding a primitive root. This method§ consists in taking any residue a of p, and determining (by the successive formation of its powers) the exponent f to which it appertains. If $f=p-1$, a is itself a primitive root of p; if not, let b be a second residue of p, not contained in the *period* of a, (*i. e.* not congruous for the modulus p to any one of the numbers a^0, a, $a^2, \ldots a^{f-1}$,) and let the exponent to which b appertains be determined. This exponent cannot (as is shown by Gauss) be identical with, nor yet a

* Euler's memoirs on this Theory are,—

(i). Theorematum quorundam ad numeros primos spectantium demonstratio. Comment. Arith. vol. i. p. 21.

(ii). Theoremata circa residua ex divisione potestatum relicta. Ibid. p. 260.

(iii). Theoremata arithmetica novo methodo demonstrata. Ibid. p. 274.

(iv). Disquisitio accuratior circa residua ex divisione quadratorum aliarumque potestatum per numeros primos relicta. Ibid. p. 487.

(v). Demonstrationes circa residua ex divisione potestatum per numeros primos resultantia. Ibid. p. 516.

† See the memoir (i) of the preceding note; and Gauss's criticism on it; Disq. Arith. Art. 56.

‡ Disq. Arith. Art. 52–55. § Ibid. Art. 73–74.

divisor of, the exponent to which a appertains; but it is always possible by a comparison of the values of a and b to determine a third number, c, which shall appertain to an exponent divisible by each of the exponents to which a and b appertain. By proceeding in this way we shall evidently obtain numbers appertaining to exponents continually higher, till at last we come to a number appertaining to the exponent $p-1$; *i. e.* to a primitive root of p.

M. Poinsot* proposes the following method. If $2, q_1, q_2 \ldots$ &c. be all the prime divisors of $p-1$, raise the numbers $\pm 1, \pm 2, \pm 3, \ldots \pm \frac{1}{2}(p-1)$, which form a system of residues prime to p, to the powers of which the indices are $2, q_1, q_2$, &c.; so as to determine all the quadratic residues of p, and its residues of the powers q_1, q_2, &c. If from the system of residues $1, 2, 3, \ldots p-1$, we successively exclude these residues of squares and higher powers, we shall have $\psi(p-1)$ numbers left, which cannot be congruous to any power having an index that divides $p-1$, and which are consequently (as may easily be shown) the primitive roots of p.

This method is very symmetrical; and if the problem proposed be to find *all* the primitive roots of p, it is sufficiently direct. But it is (like many other direct methods in the Theory of Numbers) of interminable prolixity; and becomes absolutely impracticable if p be a number even of moderate size, as it requires us to form the residues of the successive powers of the numbers $1, 2, 3 \ldots \frac{1}{2}(p-1)$. Of course, in performing this operation, the multiples of p are to be rejected as fast as they arise; but, notwithstanding this abbreviation, and others which a little experience will readily suggest, Gauss's method is, for any practical purpose, greatly preferable.

In a memoir by M. Oltramare in Crelle's Journal (vol. xlix. p. 161), several considerations are offered for facilitating the determination of the primitive roots of primes in numerous special cases. Some, however, of the general results of this memoir are erroneous, at least in expression, and the demonstrations of the more particular conclusions contained in it involve no new principle, but may be obtained by combining the definition of primitive roots with the criteria by which (as we shall hereafter see) we are enabled to decide on the quadratic or cubic characters of the residues of given primes. The following may serve as examples of the very interesting results which are thus obtained by M. Oltramare.

"If α be a prime number and $2\alpha+1$ be also a prime, 2 or α is a primitive root of $2\alpha+1$, according as α is of the form $4n+1$ or $4n+3$." Thus 2 is a primitive root of 37 and of 83, 11 is a primitive root of 23, 83 of 167, &c.

"If a be a prime number, other than 3, and if $p=2^m a+1$, where m is > 1, be also a prime, 3 is a primitive root of p, unless the congruence $3^{2^{m-1}} + 1 \equiv 0$, mod p, be satisfied." Thus 3 is a primitive root of 89, and of 137.

Theorems of the same character will be found in the Théorie des Nombres† of M. Desmarest. By their aid M. Desmarest has constructed a table giving a primitive root for every prime less than 10,000.

14. *Indices.*—If γ be a primitive root of p, the least positive residues of the $p-1$ successive powers of γ,

$$\gamma^1, \gamma^2, \gamma^3, \ldots\ldots \gamma^{p-1}$$

which we may denote by

$$\gamma_1, \gamma_2, \gamma_3, \ldots \gamma_{p-2}, 1,$$

are all incongruous for the modulus p. These residues, therefore, irrespective of the order in which they occur, coincide with the numbers $1, 2, 3 \ldots p-1$,

* Reflexions sur la Théorie des Nombres, cap. iv. art. 3.

† Paris, 1852. See pp. 275-279.

i. e. they represent the terms of a complete system of residues prime to p. If $\gamma^\kappa \equiv a$, mod p, κ, or any number congruous to κ for the modulus $p-1$, is termed the *index** of a for the primitive root or *base* γ; and this is expressed symbolically by writing

$$\kappa \equiv \text{Ind}\, a, \text{ mod } (p-1), \text{ or } \kappa \equiv \text{Ind}_\gamma a, \text{ mod } (p-1).$$

The principal properties of these indices, which it is clear are a kind of arithmetical logarithm, are as follows:—

$$(1)\ \text{Ind (AB)} \equiv \text{Ind A} + \text{Ind B, mod } (p-1).$$
$$(2)\ \text{Ind } (\text{A}^s) \equiv s \text{ Ind A, mod } (p-1).$$
$$(3)\ \text{Ind}\left(\frac{\text{A}}{\text{B}}, \text{mod } p\right) \equiv \text{Ind A} - \text{Ind B, mod } (p-1).$$

[The symbol $\left(\frac{\text{A}}{\text{B}}, \text{mod } p\right)$ is used to denote the value of x deduced from the congruence $\text{B}x \equiv \text{A}$ mod p.]

$$(4)\ \text{Ind}_{\gamma'} \text{A} \equiv \text{Ind}_\gamma \gamma' \,.\, \text{Ind}_\gamma \text{A, mod } (p-1).$$
$$(5)\ \text{If A} \equiv \text{B, mod } p, \text{ Ind A} \equiv \text{Ind B, mod } p-1.$$

In these congruences A and B represent numbers prime to p, s any integral number, and γ and γ' two different primitive roots.

The great importance of these indices in arithmetical researches has induced the Academy of Berlin to publish a volume containing tables of the numbers corresponding to given indices, and of the indices corresponding to given numbers for all primes less than 1000. This volume, the 'Canon Arithmeticus†,' was edited by C. G. J. Jacobi, and contains, besides the Tables, a preface explaining the methods which he adopted in their construction. The annexed specimen will serve to exemplify the arrangement of the Tables:—

$$p = 29$$
$$p-1 = 2^2 \cdot 7.$$

Numeri.

I.	0	1	2	3	4	5	6	7	8	9
		10	13	14	24	8	22	17	25	18
1	6	2	20	26	28	19	16	15	5	21
2	7	12	4	11	23	27	9	3	1	

Indices.

N.	0	1	2	3	4	5	6	7	8	9
		28	11	27	22	18	10	20	5	26
1	1	23	21	2	3	17	16	7	9	15
2	12	19	6	24	4	8	13	25	14	

M. Burckhardt, to whom arithmetic is indebted for an excellent Table of the divisors of numbers from 1 to 3,036,000‡, has inserted in his work, and apparently only to fill up a blank page at the end of the first million, a table stating the number of figures in the decimal period of the fraction $\frac{1}{p}$, for every prime number p less than 2500. It is evident that the number

* The reader must be careful to distinguish between the *index* of a number and the *exponent* to which the number appertains. The *exponent* does not depend on the choice of the primitive root: for a given number it has but one value, α, which is such that $\frac{p-1}{\alpha}$ is the greatest common divisor of the index and of $p-1$. The index may have any one of $\psi(\alpha)$ different values; which of these it has, depends on the particular primitive root chosen.

† Berlin, 1839.

‡ Paris, 1814–1817. A Table containing the exponents to which 10 appertains, for every prime less than 10,000, has since been given by M. Desmarest. (See p. 308 of his 'Théorie des Nombres.')

of terms in the decimal period of $\frac{1}{p}$ is nothing else than the exponent to which 10 appertains for the modulus p. M. Burckhardt's table, therefore, at once apprises us that out of the 365 primes inferior to 2500 (2 and 5 are not counted in this enumeration, as being divisors of 10), 10 is a primitive root of 148; because there are 148 primes p below 2500, the reciprocals of which have decimal periods consisting of $p-1$ figures. Again, for 108 of the remaining primes below 2500, the exponent to which 10 appertains is $\frac{1}{2}(p-1)$. Of these 108 primes, 73 are of the form $4n+3$, from which it may be inferred that -10 is a primitive root of those 73 numbers. M. Burckhardt's Table supplies us, therefore, with a primitive root (and that root the most convenient for the purposes of computation) of $148+73=221$ out of the 365 primes inferior to 2500. Nor is this the limit to its usefulness; for when the exponent to which 10 appertains is as high as $\frac{1}{2}(p-1)$ or $\frac{1}{3}(p-1)$ or $\frac{1}{4}(p-1)$, it is possible by methods which Jacobi has indicated to construct the Table of Indices with very little labour.

Jacobi says that had it not been for this table of Burckhardt's he should hardly have ventured on the construction of the 'Canon Arithmeticus,' on account of the prolixity and uncertainty of the tentative methods for the investigation of primitive roots. But, while endeavouring to avail himself of the results of M. Burckhardt's table, for the computation of his own Tables of Indices, in other cases besides those in which that Table immediately furnishes a primitive root, he was led to the invention of a general method of procedure, which, as he says, would have enabled him to dispense with the assistance of Burckhardt's Table altogether, or to extend his Canon to any higher limit which the expense of printing would have admitted. This method is not in principle very different from Gauss's process for finding primitive roots, but the form which Jacobi has given to it possesses great advantages, for the purpose to which he has applied it. He first of all takes a number a (not quite at hap-hazard, for quadratic residues can at any rate be excluded by the law of reciprocity; see *inf.* Art. 16); and determines its *period* of residues, and the exponent α to which it appertains. Let $\alpha\alpha'=p-1$, and let the residues of $a, a^2, a^3 \ldots a^\alpha$, be entered in a Table of which the arguments are the indices $1, 2, 3, \ldots p-1$, opposite to the indices, $\alpha', 2\alpha', 3\alpha' \ldots \alpha\alpha'$, respectively. It has been shown by Gauss that there are always $\frac{\psi(p-1)}{\psi(\alpha)}$ primitive roots for which this assignment is true. A number b is then taken, not contained in the period of a, and the residues of its successive powers are formed till we come to the lowest power of it that is congruous to any power of a; so that $b^{\mathrm{B}} \equiv a^{\mathrm{A}}$, mod p. Let β be the exponent to which b appertains, θ the greatest common divisor of α and β, and $\lambda=\frac{\alpha\beta}{\theta}$ their least common multiple; let also $\beta\beta'=p-1$. It may be proved that $\mathrm{B}=\frac{\beta}{\theta}$; $\mathrm{A}=\frac{k\alpha}{\theta}$; where k is some number less than θ and prime to it, so that $\frac{\alpha}{\theta}$ is the greatest common divisor of A and α. These relations show, that when we know the numbers α, A, and B, we can immediately find θ, k, and β, without having to raise b to any power higher than b^{B}. We may then assign to b any index of the form $l\beta'$, where l is prime to β, and congruous to k for the modulus θ. The number of such values of l (incongruous for the modulus β) is $\frac{\psi(\beta)}{\psi(\theta)}$;

and, whichever of them we take, there will be $\frac{\psi(p-1)}{\psi(\lambda)}$ primitive roots, for which b will have the index $l\beta'$, while a retains the index α'. We must next form the residues of the $\lambda-\alpha$ products included in the formula $a^x b^y$; where x has any value from 1 to α inclusive, and y any value from 1 to B-1. These residues are all incongruous; the indices of all of them are known; and, together with the α powers of a already entered in the table, they exhaust all the numbers which have indices divisible by $\frac{p-1}{\lambda}$.

In practice, it will almost always happen that λ is equal to $p-1$. When this is so, nothing remains to complete the operation but to enter in the Table the residues of the numbers $a^x b^y$ opposite to the indices corresponding to them. But, if $\lambda < p-1$, we may take that residue which has $\frac{p-1}{\lambda}$ for its index, and use it to replace a in the preceding operation, while b is replaced by some other residue not yet entered in the Table. In this way we shall ultimately (and in practice very speedily) obtain a complete Table of Residues corresponding to given indices, which, of course, immediately supplies us with the inverse Table of Indices corresponding to given residues. It will be seen (as has been already observed) that the process is not dissimilar to Gauss's method for determining a number appertaining to the exponent λ when we already know two numbers a and b appertaining to the exponents α and β respectively. But it is so arranged by Jacobi that hardly a single figure is wasted, the primitive root, instead of being found by a preliminary investigation, presenting itself at the end of the operation, and being recognized by its standing opposite to the index 1.

To calculate with rapidity the residues of the powers of a number, Jacobi employs a method proposed by M. Crelle in his Journal, vol. ix. p. 30, and which is most easily explained by an example.

Let $p=11$, and let it be required to determine the residues of the powers of 3; and the residues of those powers multiplied by 7.

Column	I.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
„	II.	3, 6, 9, 1, 4, 7, 10, 2, 5, 8
„	III.	3, 9, 5, 4, 1,
„	IV.	10, 8, 2, 6, 7.

The first column contains the numbers 1, 2, 3 . . $p-1$. The second column begins with 3 (the number the powers of which we are considering), and consists of numbers formed by successive additions of 3, multiples of 11 being rejected as fast as they arise. The third column also commences with 3, and is so formed that any number r in it is followed by the number which in column II. stands under r in column I. This column contains the residues of the powers of 3 taken in order, and stops at 3^5 because after that the same residues recur. Lastly, column IV. begins with 10 (the number which in column II. stands under 7 in column I.), and is formed in the same way as column III. It represents the residues of 7.3, 7.3^2, &c....

15. *Quadratic Residues.*—It appears from the theorems cited in Art. 12, that the numbers 1, 2, 3,... $p-1$, divide themselves into two classes of Quadratic Residues, and Quadratic non-Residues, comprising $\frac{1}{2}(p-1)$ numbers each. Every quadratic residue a satisfies the congruence $x^{\frac{p-1}{2}} \equiv 1, \bmod p$; every quadratic non-residue b satisfies, instead, the congruence $x^{\frac{p-1}{2}} \equiv -1$,

mod p. Again, for every quadratic residue the congruence $x^2 \equiv a$, mod p, is resoluble; for every non-quadratic residue the congruence $x^2 \equiv b$, mod p, is irresoluble. The solution of almost every problem relating to the indeterminate analysis of quadratic functions involves a congruence of the simple form $x^2 \equiv A$, mod p. It is therefore of great importance to obtain a criterion which shall enable us to determine *a priori* whether a given number is or is not a quadratic residue of a given prime. If we have a Table of Indices for the given prime, we have only to see whether the index of the given number is even or uneven; if even, it is a quadratic residue; if uneven, it is a quadratic non-residue. Or, again, we may raise the given number a (by M. Crelle's method, or any other) to the power $\frac{p-1}{2}$, and see whether the residue is $+1$ or -1. It is usual to denote the positive or negative unit which is the remainder of $a^{\frac{p-1}{2}}$, mod p by the symbol $\left(\frac{a}{p}\right)$, which is known as "Legendre's Symbol;" so that in every case $a^{\frac{p-1}{2}} \equiv \left(\frac{a}{p}\right)$, mod p, and $\left(\frac{a}{p}\right) = +1$ or $= -1$, according as a is or is not a quadratic residue of p. It will be seen that we also have in every case the equation $\left(\frac{a_1}{p}\right)\left(\frac{a_2}{p}\right) = \left(\frac{a_1 a_2}{p}\right)$. If a instead of being prime to p be divisible by p, it is convenient to attribute to $\left(\frac{a}{p}\right)$ the value zero.

16. *Legendre's Law of Reciprocity.*—The two methods alluded to for the discrimination of quadratic and non-quadratic residues, or, which is the same thing, for the determination of the value of the symbol $\left(\frac{a}{p}\right)$, are not satisfactory,—the first because it supposes a reference to a Table of Indices (*i. e.* to a recorded solution of the problem it is proposed to solve), the second on account of its inapplicability to high numbers. A very different solution of the problem is supplied by a theorem which is known as "Legendre's Law of Quadratic Reciprocity," and which is, without question, the most important general truth in the science of integral numbers which has been discovered since the time of Fermat. It has been called by Gauss "the gem of the higher arithmetic," and is equally remarkable whether we consider the simplicity of its enunciation, the difficulties which for a long time attended its demonstration, or the number and variety of the results which have been obtained by its means. The theorem is as follows:—

"If p and q be two *uneven* prime numbers

$$\left(\frac{p}{q}\right) = (-1)^{\frac{1}{4}(p-1)(q-1)}\left(\frac{q}{p}\right)\text{"}, \text{(i)};$$

to which we must add the complementary propositions relating to the residues -1 and 2

$$\left(\frac{-1}{p}\right) = (-1)^{\frac{1}{2}(p-1)} \quad \text{(ii)}; \quad \left(\frac{2}{p}\right) = (-1)^{\frac{p^2-1}{8}} \quad \text{(iii)}.$$

In (ii), p is supposed to be positive; in (i), p and q are supposed not to be simultaneously negative.

The equation $\left(\frac{p}{q}\right)\left(\frac{q}{p}\right)=(-1)^{\frac{1}{4}(p-1)(q-1)}$ may be expressed in words by saying that "if p and q be two primes, the quadratic character of p in regard to q is the same as the quadratic character of q in regard to p; except both p and q be of the form $4n+3$, in which case the two characters are opposite instead of identical."

Gauss, who attributes the first enunciation of this theorem to Legendre, while he justly claims the first demonstration of it for himself*, appears to have considered that Euler was unacquainted with the theorem, at least in its simple form. (See Disq. Arith. Art. 151.) Nevertheless, we find in the 'Opuscula Analytica' of Euler, vol. i. p. 64, a memoir† the concluding paragraph of which contains a general and very elegant theorem, from which the Law of Reciprocity is immediately deducible, and which is, *vice versâ*, deducible from that law. But Euler (*loc. cit.*) expressly observes that the theorem is undemonstrated; and this would seem to be the only place in which he mentions it in connexion with the theory of the Residues of Powers; though in other researches he has frequently developed results which are consequences of the theorem, and which relate to the linear forms of the divisors of quadratic formulæ. But here also his conclusions repose on induction only; though in one memoir he seems to have imagined (for his language is not very precise) that he had obtained a satisfactory demonstration. The theorem, in a form precisely equivalent to that in which we have cited it, was first given by Legendre, in a Memoir contained in the 'Histoire de l'Académie des Sciences' for 1785. (See pp. 516, 517.) But the demonstration with which he has accompanied it is invalid for several reasons. (See Gauss, Disq. Arith. Art. 151, 296, 297, and the Additamenta.)

17. *Jacobi's extension of Legendre's Symbol.*—The symbol $\left(\frac{q}{p}\right)$, the introduction of which has greatly contributed to simplify the theories of the higher arithmetic, does not appear in the Memoir just referred to. It first occurs in the 'Essai sur la Théorie des Nombres;' the first edition of which appeared at Paris in 1798, and the second in 1808.

Jacobi, in a note communicated to the Academy of Berlin in 1837‡, has extended the notation of Legendre. If $P=p_1 p_2 p_3 \ldots\ldots$ where $p_1 p_2 p_3$ denote (equal or unequal) uneven prime numbers, Jacobi defines the symbol $\left(\frac{k}{P}\right)$ by the equation

$$\left(\frac{k}{P}\right)=\left(\frac{k}{p_1}\right)\left(\frac{k}{p_2}\right)\left(\frac{k}{p_3}\right)\ldots\ldots$$

and observes that we then have the equations

$$\left(\frac{P}{Q}\right)=(-1)^{\frac{1}{4}(P-1)(Q-1)}\left(\frac{Q}{P}\right), \text{(i)}$$

* "Pro primo hujus elegantissimi Theorematis inventore ill. Legendre absque dubio habendus est, postquam longe antea summi geometræ Euler et Lagrange plures ejus casus speciales jam per inductionem detexerant. . . . . In ipsum theorema proprio marte incideram anno 1795, dum omnium, quæ in arithmetica sublimiori jam elaborata fuerant, penitus ignarus, et a subsidiis literariis omnino præclusus essem. Sed per integrum annum me torsit, operamque enixissimam effugit," etc.—Comm. Soc. Gött. vol. xvi. p. 69.

† Observationes circa divisionem quadratorum per numeros primos (Comment. Arith. vol. i. p. 477).

‡ Ueber die Kreistheilung und ihre Anwendung auf die Zahlentheorie. See the Monats-Bericht of the Berlin Academy, vol. ii. p. 127 (Oct. 16, 1857), or Crelle's Journal, vol. xxx. p. 166.

$$\left(\frac{-1}{P}\right)=(-1)^{\frac{1}{2}(P-1)}, \text{ (ii)}, \left(\frac{2}{P}\right)=(-1)^{\frac{P^2-1}{8}}, \text{ (iii)}$$

P and Q denoting any two uneven numbers relatively prime, the signs of which are subject to the same restrictions as the signs of p and q in the corresponding formula of Art. 16. The theorems expressed by these formulæ of Jacobi are very easily deducible from the formulæ of Legendre, and will be found in the Disq. Arith. (Art. 133). To prevent misconception, however, it is proper to observe, that while Legendre's equation $\left(\frac{k}{p}\right)=1$ is a necessary and sufficient condition for the resolubility of the congruence $x^2 \equiv k$, mod p, Jacobi's equation $\left(\frac{k}{P}\right)=1$, where P is not a prime number, though a necessary, is not a sufficient condition for the resolubility of the corresponding congruence $x^2 \equiv k$, mod P. That congruence requires for its resolubility that the conditions $\left(\frac{k}{p_1}\right)=1$, $\left(\frac{k}{p_2}\right)=1$ .... should separately be satisfied; p_1 p_2 ... denoting the unequal prime factors of P.

Gauss (who had in the course of his own early researches arrived independently at the Law of Quadratic Reciprocity), before finally abandoning the theory, succeeded in obtaining no fewer than six demonstrations of this fundamental proposition. The first two are contained in the Disq. Arith. (Art. 125–145, and Art. 262); the third and fourth in two memoirs presented in 1808 to the Society of Göttingen (Comm. Soc. Gött. vol. xvi. p. 69, Jan. 15, and Comm. Recentiores, vol. i., Aug. 24), of which the latter bears the title 'Summatio serierum quarundam singularium.' The fifth and sixth appeared nine years later in the memoir entitled 'Theorematis Fundamentalis in doctrina de Residuis quadraticis demonstrationes et ampliationes novæ' (Comm. Rec. vol. iv. p. 3, Feb. 10, 1817). The fourth of these demonstrations is probably that which is promised in the Disq. Arith., Art. 151, but which does not appear in that work, because (as it would seem) Gauss had not yet succeeded in overcoming the difficulties connected with it.

Independently of the fundamental importance of Legendre's Law of Reciprocity, these demonstrations of Gauss possess such intrinsic interest, and have contributed so much to the progress of the science, that we shall briefly review them here.

18. *Gauss's First Demonstration.*—The first demonstration (Disq. Arith. Art. 125–145), which is presented by Gauss in a form very repulsive to any but the most laborious students, has been resumed by Lejeune Dirichlet in a memoir in Crelle's Journal (vol. xlvii. p. 139), and has been developed by him with that luminous perspicuity by which his mathematical writings are distinguished.

Let λ represent any uneven prime. The single observation that $\left(\frac{3}{5}\right)=-1$ $=\left(\frac{5}{3}\right)$ shows that the theorem of reciprocity is true for primes inferior to 7. To establish its universal truth, it is, consequently, sufficient to show that, if true for all primes up to λ exclusively, it is also true for all primes up to λ inclusively. Let the theorem therefore be assumed to be true for all primes inferior to λ; let p be any one of those primes; and let the eight cases $[2 \times 2 \times 2 = 8]$ be considered separately, which arise from every possible combination of the hypotheses (α) $\left(\frac{p}{\lambda}\right)=+1$, or

$=-1$; (β) $\lambda\equiv 1$, or $\equiv 3$, mod 4; (γ) $p\equiv 1$, or $\equiv 3$, mod 4. It has to be shown that, in each of these eight cases, the symbol $\left(\frac{\lambda}{p}\right)$ actually has the value which the Law of Reciprocity assigns to it. The nature of the proof in the four cases in which $\left(\frac{p}{\lambda}\right)=+1$, will be rendered intelligible by a single example.

Let $\left(\frac{p}{\lambda}\right)=1$ and let $\lambda\equiv p\equiv 1$, mod 4. By virtue of the symbolic equation $\left(\frac{p}{\lambda}\right)=1$, we can establish the congruence $x^2\equiv p$, mod λ, or (which is the same thing) the equation $x^2=p+\lambda y$; in which we may suppose x *even* and less than λ, y positive, less than λ and of the form $4n+3$. From this equation it appears that $\left(\frac{\lambda y}{p}\right)=1$, and $\left(\frac{p}{y}\right)=1$, the symbol $\left(\frac{p}{y}\right)$ being here used with the meaning Jacobi has assigned to it. But every prime divisor of y is less than λ; and, therefore, by Jacobi's formula of reciprocity (which is valid for all uneven numbers less than λ, since by hypothesis Legendre's law is valid for all primes less than λ), $\left(\frac{y}{p}\right)=\left(\frac{p}{y}\right)=1$. But $\left(\frac{\lambda y}{p}\right)=1=\left(\frac{\lambda}{p}\right)\left(\frac{y}{p}\right)$; so that, finally, $\left(\frac{\lambda}{p}\right)=1$ in conformity with Legendre's law. We have here assumed that x is prime to p; a slight modification in the proof will adapt it to the contrary supposition.

Again, the two cases in which $\left(\frac{p}{\lambda}\right)=-1$, and $\lambda\equiv 3$, mod 4, admit of similar treatment. For the equation $\left(\frac{p}{\lambda}\right)=-1$ involves also the equation $\left(\frac{-p}{\lambda}\right)=+1$, because $\lambda\equiv 3$, mod 4. We have therefore the congruence $x^2\equiv -p$, mod λ, which will serve to replace the congruence $x^2\equiv p$, mod λ, which presents itself in the four cases first mentioned.

But the two remaining cases, in which $\left(\frac{p}{\lambda}\right)=-1$, $\lambda\equiv 1$, mod 4, require a different mode of treatment. By a singularly profound analysis, Gauss has succeeded in showing that every prime of the form $4n+1$ is a non-quadratic residue of some prime less than itself. Assume, therefore, the existence of a prime ϖ, less than λ, and satisfying the condition $\left(\frac{\lambda}{\varpi}\right)=-1$. This condition implies that $\left(\frac{\varpi}{\lambda}\right)=-1$; for if $\left(\frac{\varpi}{\lambda}\right)$ were equal to $+1$, we should have $\left(\frac{\lambda}{\varpi}\right)=+1$, by one of the first four cases. Hence we may infer that $\left(\frac{\varpi p}{\lambda}\right)=+1$, and may establish the congruence $x^2\equiv\varpi p$, mod λ, which, treated as in the preceding cases, will lead us to the conclusion that $\left(\frac{\lambda}{p}\right)\left(\frac{\lambda}{\varpi}\right)=1$, *i. e.* that $\left(\frac{\lambda}{p}\right)=-1$.

19. *Gauss's Second, Third, and Fifth Demonstrations.*—The second demonstration (Disq. Arith. 262) depends on the theory of quadratic forms, and will be referred to in its proper place in this Report.

The third and fifth (which are in principle very similar to one another) depend on much simpler considerations.

A *half-system of Residues for a prime modulus p* is a system of $\frac{1}{2}(p-1)$ numbers $r_1 r_2 \ldots r_{\frac{1}{2}(p-1)}$, such that the $p-1$ numbers $\pm r_1, \pm r_2 \ldots \pm r_{\frac{1}{2}(p-1)}$ constitute a system of residues prime to p. We might take for the numbers $r_1 r_2$ &c., the even numbers less than p (as Eisenstein has done: see Crelle's Journal, vol. xxviii. p. 246), but Gauss has preferred to take the numbers $1, 2, 3 \ldots \frac{1}{2}(p-1)$.

Let q be any number prime to p, and let k be the number of the numbers, $qr_1, qr_2, qr_3 \ldots qr_{\frac{1}{2}(p-1)}$, which are congruous, not to numbers in the series $r_1, r_2 \ldots r_{\frac{1}{2}(p-1)}$, but to numbers in the series $-r_1, -r_2, \ldots -r_{\frac{1}{2}(p-1)}$. It may be shown (by a method similar to that employed in Dirichlet's proof of Fermat's Theorem) that $q^{\frac{1}{2}(p-1)} \equiv (-1)^k$, mod p; so that $\left(\frac{q}{p}\right) = (-1)^k$. Hence if q be a prime as well as p, and k' denote the number which replaces k, when p and q are interchanged in the preceding considerations, we find that $\left(\frac{p}{q}\right)\left(\frac{q}{p}\right) = (-1)^{k+k'}$.

It has, therefore, to be shown that $k+k' \equiv \frac{1}{4}(p-1)(q-1)$, mod 2. The way in which this is done is different in each of the two demonstrations, and is a little complicated in each of them; but by the aid of a diagram the congruence may be demonstrated intuitively (compare Eisenstein: Crelle, xxviii. p. 246). With a pair of axes Ox and Oy construct a system of unit-points in a plane: only let no such points be constructed on the axes themselves. If S be any geometrical figure, let (S) stand for the number of unit-points contained inside it or on its contour. On Ox and Oy respectively take $OA=\frac{1}{2}q$, $OB=\frac{1}{2}p$. Complete the parallelogram OACB, and draw its diagonals, OQC, AQB. It is then easily seen that

$$\begin{aligned} k &= (QCA) - (QBO) \\ k' &= (QBC) - (QOA) \\ k+k' &= (ABC) - (AOB) \\ &= (OABC) - 2(AOB) \\ &\equiv (OABC), \text{ mod } 2. \end{aligned}$$

But $(OABC) = \frac{1}{4}(p-1)(q-1)$; therefore, finally, $k+k' \equiv \frac{1}{4}(p-1)(q-1)$, mod 2.

These demonstrations (the 1st, 3rd and 5th) introduce no heterogeneous elements into the inquiry (the geometrical method of the preceding article is to be regarded only as an abbreviation of an equivalent and purely arithmetical process); they are based on the principles of the two theories with which the Law of Reciprocity is most intimately connected,—those of the residues of powers, and of quadratic congruences. The third, in particular, appears to have commended itself above the rest to Gauss's judgment*.

* "Sed omnes hæ demonstrationes," (he is speaking, apparently, of the 1st, 2nd, 4th, and 6th,) "etiamsi respectu rigoris nihil desiderandum relinquere videantur, e principiis nimis heterogeneis derivatæ sunt; primâ forsan exceptâ, quæ tamen per ratiocinia magis laboriosa procedit, operationibusque prolixioribus premitur. Demonstrationem itaque *genuinam* hactenus haud affuisse non dubito pronunciare; esto jam penes peritos judicium, an ea, quam nuper detegere successit," (the 3rd,) "hoc nomine decorari mereatur."—Comm. Soc. Gott. vol. xvi. p. 70.

20. *Gauss's Fourth Demonstration.*—The fourth and sixth demonstrations, though somewhat different from one another, are both intimately connected with the theory of the division of the circle. They must, therefore, be regarded as less direct than the earlier proofs, but they have contributed even more to the methods and resources of the higher arithmetic.

The fourth depends on the formula

$$1+r+r^4+r^9+\ldots\ldots+r^{(n-1)^2}=i^{\frac{1}{4}(n-1)^2}\sqrt{n}\ldots\ldots(\mathrm{A})$$

in which i represents (as throughout this Report) an imaginary square root of -1; n is any uneven number, $\sqrt{n}$ its positive square root, $r=\cos\frac{2\varpi}{n}+i\sin\frac{2\varpi}{n}$. Let the series

$$1+r^k+r^{4k}+r^{9k}+\ldots+r^{(n-1)^2k} \text{ be denoted by } \psi\,(k,n)\,;$$

in the particular case in which n is a prime number, it is easy to see that $\psi\,(k,n)=\left(\frac{k}{n}\right)\psi\,(1,n)$. Further, p and q denoting two prime numbers, it is found by actual multiplication of the two series $\psi\,(p,q)$ and $\psi\,(q,p)$ that

$$\psi\,(p,q)\times\psi\,(q,p)=\psi\,(1,pq);\text{ that is }\left(\frac{p}{q}\right)\left(\frac{q}{p}\right)=\frac{\psi\,(1,pq)}{\psi\,(1,p)\,\psi\,(1,q)}.$$

If we substitute for the functions ψ their values given by the equation (A), we find $\left(\frac{p}{q}\right)\left(\frac{q}{p}\right)=i^{\frac{1}{4}(pq-1)^2-\frac{1}{4}(p-1)^2-\frac{1}{4}(q-1)^2}$, an equation which gives a relation between $\left(\frac{p}{q}\right)$ and $\left(\frac{q}{p}\right)$ coincident with that assigned in Legendre's Law of Reciprocity.

The equation (A) is not easy to demonstrate. It is not indeed difficult to show that the sum of the series on the left-hand side is $\pm\sqrt{n}$ when $n\equiv 1$, mod 4; and $\pm i\sqrt{n}$ when $n\equiv 3$, mod 4. But the determination of the ambiguous sign in these values appears to have long occupied Gauss. He has effected it in his memoir (the Summatio Serierum, &c.) by establishing the equality

$$1+r+r^4+r^9+\ldots+r^{(n-1)^2}=(r-r^{-1})\,(r^3-r^{-3})\ldots\ldots(r^{n-2}-r^{-n+2})\ldots\ldots(\mathrm{B}),$$

which he obtains by writing r for x, and $n-1$ for m, in the series

$$1-\frac{1-x^m}{1-x}+\frac{(1-x^m)\,(1-x^{m-1})}{(1-x)\,(1-x^2)}-\frac{(1-x^m)\,(1-x^{m-1})\,(1-x^{m-2})}{(1-x)\,(1-x^2)\,(1-x^3)}+\ldots$$

This series when m is a positive integer becomes an integral algebraical function, and is proved by Gauss to be zero if m be uneven; and if m be even, to be equal to the product $(1-x)\,(1-x^2)\ldots(1-x^{m-1})$. From this last observation, the demonstration of the formula (B) naturally flows. If n be an uneven number, the formula (A) becomes

$$1+r+r^4+r^9+\ldots+r^{(n-1)^2}=(1+i)\sqrt{n}\text{ or}=0 \qquad (\mathrm{A}')$$

according as n is evenly or unevenly even.

A very different, but a simpler demonstration of these formulæ (A) and (A′), depending on the properties of the definite integrals

$$\int_{-\infty}^{+\infty}\cos x^2\,dx,\ \int_{-\infty}^{+\infty}\sin x^2\,dx,\text{ or }\int_{-\infty}^{+\infty}\epsilon^{ix^2}\,dx,$$

has been given by Dirichlet in his memoir, "Application de l'Analyse Infinitésimale à la Théorie des Nombres" (Crelle, vol. xxi. p. 135).

The same formulæ have also been deduced by Cauchy from the equation

$$a^{\frac{1}{2}}\left(\tfrac{1}{2}+\epsilon^{-a^2}+\epsilon^{-4a^2}+\epsilon^{-9a^2}+\ldots\right)=b^{\frac{1}{2}}\left(\tfrac{1}{2}+\epsilon^{-b^2}+\epsilon^{-4b^2}+\epsilon^{9b^2}+\ldots\right),$$

or
$$\tfrac{1}{2}+\epsilon^{-a^2}+\epsilon^{-4a^2}+\epsilon^{-9a^2}+\ldots=\frac{\sqrt{\varpi}}{a}\left(\tfrac{1}{2}+\epsilon^{-b^2}+\epsilon^{-4b^2}+\epsilon^{-9b^2}+\ldots\right),$$

in which $ab=\varpi$, a and b denoting real positive quantities, or imaginary quantities the real parts of which are positive. This equation Cauchy obtained, as early as 1817, by the principles of his theory of reciprocal functions; but it is also deducible from known elliptic formulæ. (See a note by M. Lebesgue in Liouville's Journal, vol. v. p. 186.) If in it we write $\alpha^2-\dfrac{2i\varpi}{n}$ for a^2, and $\beta^2+\dfrac{ni\varpi}{2}$ for b^2, α and β being two evanescent quantities connected by the relation $n\alpha=2\beta$, the two series

$$n\alpha\left(\tfrac{1}{2}+\epsilon^{-a^2}+\epsilon^{-4a^2}+\epsilon^{-9a^2}+\ldots\right)$$

and
$$2\beta\left(\tfrac{1}{2}+\epsilon^{-b^2}+\epsilon^{-4b^2}+\epsilon^{-9b^2}+\ldots\right)$$

become respectively $\psi(1,n)\times\displaystyle\int_0^\infty \epsilon^{-x^2}\,dx$, and $\left(1+\epsilon^{-\frac{ni\varpi}{2}}\right)\times\displaystyle\int_0^\infty \epsilon^{-x^2}\,dx$;

whence, dividing by the definite integral, and observing that $a=\sqrt{\dfrac{2\varpi}{n}}\,\epsilon^{-\frac{i\varpi}{4}}$,

we obtain finally, in accordance with the formulæ of Gauss,

$$\psi(1,n)=\tfrac{1}{2}\sqrt{n}(1+i)\left(1+\epsilon^{-\frac{ni\varpi}{2}}\right)^*.$$

For the case in which n is a prime number, the equality (B) has been established in a very simple manner by M. Cauchy† and M. Kronecker‡. But, as these latter methods have not been extended to the case in which n is a composite number, they cannot be used to replace Gauss's analysis in this demonstration of the law of reciprocity.

From the formula (A) combined with the equation $\psi(k,p)=\left(\dfrac{k}{p}\right)\psi(1,p)$, p denoting a prime number, we may infer

$$\left(\frac{k}{p}\right)\sqrt{p}=\sum_{s=0}^{s=p-1}\cos s^2\frac{2k\varpi}{p};\quad \sum_{s=0}^{s=p-1}\sin s^2\frac{2k\varpi}{p}=0;$$

or
$$\left(\frac{k}{p}\right)\sqrt{p}=\sum_{s=0}^{s=p-1}\sin s^2\frac{2k\varpi}{p};\quad \sum_{s=0}^{s=p-1}\cos s^2\frac{2k\varpi}{p}=0,$$

according as $p\equiv1$, or $\equiv3$, mod 4.

These formulæ serve to express the value of the symbol $\left(\dfrac{k}{p}\right)$ by means of a finite trigonometrical series, and are, therefore, of very great importance.

* See M. Cauchy's Mémoire sur la Théorie des Nombres in the Mémoires de l'Académie de France, vol. xvii. notes ix. x. and xi. See also the Comptes Rendus for April 1840, or Liouville's Journal, vol. v. p. 154; and compare (beside the note of M. Lebesgue quoted in the text) a memoir by the same author in Liouville, vol. v. p. 42.

† In the Mémoire sur la Théorie des Nombres, Note xi., or Liouville, vol. v. p. 161.

‡ Liouville, New Series, vol. i. p. 392.

Conversely, the circumstance that a trigonometrical summation should depend on the quadratic characters of integral numbers, may serve of itself to show the use of abstract arithmetical speculations in other parts of analysis.

21. *Gauss's Sixth Demonstration.*—This demonstration depends on an investigation of certain properties of the algebraical function

$$\xi_k = \sum_{s=0,}^{s=p-2} (-1)^s x^{k\gamma^s}$$

in which p is a prime number, γ a primitive root of p, k any number prime to p, and x an absolutely indeterminate symbol. These properties are as follows:—

(1) $\xi_k^2 - (-1)^{\frac{p-1}{2}} p$ is divisible by $\frac{1-x^p}{1-x}$,

(2) $\xi_k - \left(\frac{k}{p}\right)\xi_1$ is divisible by $1-x^p$,

(3) If $k=q$ be a prime number,
$\xi_1{}^q - \xi_q$ is divisible by q.

From (1) we may infer that $\xi_1{}^{q-1} - (-1)^{\frac{1}{4}(p-1)(q-1)} p^{\frac{q-1}{2}}$ is divisible by $\frac{1-x^p}{1-x}$; and, by combining this inference with (1) and (2), we may conclude that $\xi_1(\xi_1{}^q - \xi_q) - (-1)^{\frac{p-1}{2}} p \left[(-1)^{\frac{1}{4}(p-1)(q-1)} p^{\frac{q-1}{2}} - \left(\frac{q}{p}\right)\right]$

is also divisible by $\frac{1-x^p}{1-x}$; that is to say,

$$(-1)^{\frac{p-1}{2}} p \left[(-1)^{\frac{1}{4}(p-1)(q-1)} p^{\frac{q-1}{2}} - \left(\frac{q}{p}\right)\right]$$

is the remainder left in the division of the function $\xi_1(\xi_1{}^q - \xi_q)$ by $\frac{1-x^p}{1-x}$. But every term in that function is divisible by q; the remainder is therefore itself divisible by q. We thus obtain the congruence

$$(-1)^{\frac{1}{4}(p-1)(q-1)} p^{\frac{q-1}{2}} \equiv \left(\frac{q}{p}\right), \bmod q,$$

which involves the equation $\left(\frac{p}{q}\right)\left(\frac{q}{p}\right) = (-1)^{\frac{1}{4}(p-1)(q-1)}$.

Gauss has given a purely algebraical proof of the theorems (1), (2), and (3), on which this demonstration depends. The third is a simple consequence of the arithmetical property of the multinomial coefficient, already referred to in Art. 10 of this Report; to establish the first two, it is sufficient to observe that $\xi_k^2 - (-1)^{\frac{p-1}{2}} p$, and $\xi_k - \left(\frac{k}{p}\right)\xi_1$ vanish, the first, if x be any imaginary root, the second, if x be any root whatever, of the equation $x^p - 1 = 0$. If, for example, in the function ξ_k we put $x = r = \cos\frac{2\varpi}{p} + i \sin\frac{2\varpi}{p}$, we obtain the function $\psi(k, p)$, which satisfies, as we have seen, the two equations $[\psi(k,p)]^2 = (-1)^{\frac{p-1}{2}} p$, and $\psi(k,p) = \left(\frac{k}{p}\right)\psi(1,p)$. It is, indeed, simplest to suppose $x=r$ throughout the whole demonstration, which is thus seen to depend wholly on the properties of the same trigonometrical function ψ, which presents itself in the fourth demonstration; only it will be observed that here no necessity arises for the consideration of composite values of n in the function $\psi(k, n)$; nor for the determination of the ambiguous sign in the formula (A). In this specialized form, Gauss's sixth proof has been given by Jacobi (in the 3rd edit. of Legendre's 'Théorie des Nombres,' vol. ii. p. 391), Eisenstein (Crelle, vol. xxviii. p. 41), and Cauchy (Bulletin de Férussac, Sept. 1829, and more fully Mém. de l'Institut, vol. xviii. p. 451, note iv. of the Mémoire), quite independently of one another, but apparently without its being at the time perceived by any of those eminent geometers that they were closely following Gauss's method. (See Cauchy's Postscript at the end of the notes to his Mémoire; also a memoir by M. Lebesgue in Liouville, vol. xii. p. 457; and a foot-note by Jacobi, Crelle, vol. xxx. p. 172, with Eisenstein's reply to it, Crelle, vol. xxxv. p. 273.)

MM. Lebesgue * and Eisenstein † have even exhibited a proof essentially the same in a purely arithmetical form, from which the root of unity again disappears, and is replaced by unity itself. Eisenstein considers the sum $C_a = \Sigma\left(\frac{k_1}{p}\right)\left(\frac{k_2}{p}\right)\cdots\left(\frac{k_q}{p}\right)$, in which $k_1, k_2, \ldots k_q$ denote q terms (equal or unequal) of a system of residues prime to p, the sign of summation extending to every combination of the numbers $k_1, k_2, \ldots k_q$, that satisfies the congruential condition $k_1+k_2+k_3+\ldots+k_q \equiv a$, mod p. This sum is, in fact, the coefficient of r^a in the development of the qth power of the function $\sum_{k=1}^{k=p-1}\left(\frac{k}{p}\right)r^k$, which is equivalent in value to Gauss's function $\psi(1, p)$.

From the equation $\left[\sum_{k=1}^{k=p-1}\left(\frac{k}{p}\right)r^k\right]^2 = (-1)^{\frac{1}{2}(p-1)}\,p$, it follows that

$$\left[\sum_{k=1}^{k=p-1}\left(\frac{k}{p}\right)r^k\right]^q = (-1)^{\frac{1}{4}(p-1)(q-1)}\,p^{\frac{1}{2}(q-1)} \times \sum_{k=1}^{k=p-1}\left(\frac{k}{p}\right)r^k;$$ whence

$C_a = (-1)^{\frac{1}{4}(p-1)(q-1)}\left(\frac{a}{p}\right)p^{\frac{q-1}{2}}$. And again, since $\left[\sum_{k=1}^{k=p-1}\left(\frac{k}{p}\right)r^k\right]^q$ $\equiv \sum_{k=1}^{k=p-1}\left(\frac{k}{p}\right)r^{kq} \equiv \left(\frac{q}{p}\right)\sum_{k=1}^{k=p-1}\left(\frac{k}{p}\right)r^k$, mod q, we have the congruence $C_a \equiv \left(\frac{a}{p}\right)\left(\frac{q}{p}\right)$, mod q. But these results, which, taken together, establish the law of reciprocity, are obtained by Eisenstein from his arithmetical definition of C_a, without any reference to the trigonometrical function $\psi(1, p)$. If we write that function in the form $\sum_{k=0}^{k=p-1} r^{k^2}$, instead of the form $\sum_{k=1}^{k=p-1}\left(\frac{k}{p}\right)r^k$, we obtain from its qth power the coefficient C'_a considered by M. Le-

* See Liouville's Journal, vol. ii. p. 253, and vol. iii. p. 113. (The proof of the law of reciprocity will be found in sect. i. art. 5, and sect. iii. art. 2, of the memoir). See also the memoir referred to in the text, Liouville, vol. xii. p. 457.

† Crelle's Journal, vol. xxvii. p. 322.

besgue. This coefficient, which is connected with C_a by the equation $C'_a=p^{q-1}+C_a$, represents the number of solutions of the congruence $x_1^2+x_2^2+x_3^2+..+x_q^2\equiv a$, mod q. From this definition M. Lebesgue deduces the equation $C'_a=p^{q-1}+(-1)^{\frac{1}{4}(p-1)(q-1)}\left(\frac{a}{p}\right)p^{\frac{q-1}{2}}$, and the congruence $C'_a\equiv 1+\left(\frac{a}{p}\right)\left(\frac{q}{p}\right)$, mod q, by processes which, though different from those of Eisenstein, involve, like them, the consideration of integral numbers only.

22. Other proofs of the Theorem of Reciprocity have been suggested to subsequent writers by a comparison of the different methods of Gauss. The symbol r denoting a root of the equation $\frac{x^p-1}{x-1}=0$, it is very easily shown that

$$(r-r^{-1})^2\,(r^2-r^{-2})^2\ldots\ldots\left(r^{\frac{p-1}{2}}-r^{-\frac{p-1}{2}}\right)^2=(-1)^{\frac{p-1}{2}}p. \qquad \text{(C)}$$

It is natural therefore to employ this equation to replace the equation $\left[\sum_{k=1}^{k=p-1}\left(\frac{k}{p}\right)r^k\right]^2=(-1)^{\frac{p-1}{2}}p$, which presents itself in the 4th and 6th methods of Gauss. It is also found that the product

$$\prod_{k=1}^{k=\frac{1}{2}(p-1)}\frac{r^{kq}-r^{-kq}}{r^q-r^{-q}} \text{ is equal to } \left(\frac{q}{p}\right). \qquad \text{(D)}$$

This is an immediate consequence of the property of *a half-system* of Residues (see Art. 19 *suprà*) on which Gauss's 3rd and 5th methods depend. From a combination of the equations (C) and (D), the law of reciprocity is immediately deducible. (See a note by M. Liouville, Compt. Rend. vol. xxiv., or Liouville's Journal, vol. xii. p. 95, and especially a memoir by Eisenstein, entitled "Application de l'Algèbre à l'Arithmétique transcendante," Crelle, vol. xxix. p. 177. The proof by the same author in vol. xxxv. p. 257, is the same as that in the earlier memoir, only that the properties of the circular functions, which here replace the roots of unity, are in the later memoir deduced immediately from the definition of the sine as the product of an infinite number of factors.)

23. *Algorithm for the Determination of the Value of the Symbol* $\left(\frac{Q}{P}\right)$.—Gauss has shown in the memoir "Demonstrationes et ampliationes novæ," already quoted, that, if p be a prime number, the value of the symbol $\left(\frac{Q}{p}\right)$ may be obtained by developing the vulgar fraction $\frac{Q}{p}$ in a continued fraction, and considering the evenness or unevenness of a certain function of the quotients and remainders which present themselves in the development. Jacobi has observed (see Crelle, vol. xxx. p. 173) that a much simpler rule may be obtained, by the use of his extension of Legendre's symbol to the case when p is not a prime. The following is the form in which the rule has been exhibited by Eisenstein (see Crelle, vol. xxvii. p. 319). Let p_1, p_2 be two uneven numbers prime to one another, and let us form by division the series of equations

$$\begin{aligned} p_1 &= 2k_1p_2 \quad +\epsilon_2 p_3 \\ p_2 &= 2k_2p_3 \quad +\epsilon_3 p_4 \dots \\ &\dots\dots\dots\dots\dots \\ p_\mu &= 2k_\mu p_{\mu+1} + \epsilon_{\mu+1}, \end{aligned}$$

in which $\epsilon_2, \epsilon_3 \dots \epsilon_{\mu+1}$ denote positive or negative units, and $p_1, p_2, p_3 \dots\dots$ which are all positive and uneven, form a descending series. Let σ denote the number of the quantities $p_r + \epsilon_r p_{r+1}$ in which *both* p_r and $\epsilon_r p_{r+1}$ are of the form $4n+3$; then $\left(\frac{p_1}{p_2}\right) = (-1)^\sigma$. The demonstration of this result flows immediately from the definition of Jacobi's symbol of reciprocity.

A numerical example is added (see Disq. Arith. Art. 328) from which the reader will perceive the utility of these researches in their practical application to congruences.

Let the proposed congruence be $x^2 \equiv -286$, mod 4272943, where 4272943 is a prime number.

We have to investigate the value of the symbol $\left(\frac{-286}{p}\right)$, in which p is written for 4272943. Now $\left(\frac{-286}{p}\right) = \left(\frac{-1}{p}\right) \times \left(\frac{2}{p}\right) \times \left(\frac{143}{p}\right) = -\left(\frac{143}{p}\right)$, because $\left(\frac{-1}{p}\right) = -1$, and $\left(\frac{2}{p}\right) = +1$, p being of the form $8n-1$. To find the value of $\left(\frac{143}{p}\right)$, we have

$$\begin{aligned} 143 &= 0 \times 4272943 + 143 \dagger \\ 4272943 &= 29880 \times 143 + 103 \dagger \\ 143 &= 2 \times 103 - 63 \\ 103 &= 2 \times 63 - 23 \\ 63 &= 2 \times 23 + 17 \\ 23 &= 2 \times 17 - 11 \\ 17 &= 2 \times 11 - 5 \dagger \\ 11 &= 2 \times 5 + 1 \end{aligned}$$

The obelisk (†) denotes that the equation to which it is affixed is one of those enumerated in σ. Hence $\left(\frac{143}{4272943}\right) = (-1)^3 = -1$, and $\left(\frac{-286}{4272943}\right) = +1$, or the proposed congruence is resoluble. Its roots (as determined by Gauss) are ± 1493445.

24. *Biquadratic Residues.*—Reverting to the general theory alluded to in Art. 12, we see that, when p is a prime of the form $4n+1$, the congruence $x^4 - 1 \equiv 0$, mod p, admits four incongruous solutions; these are $+1$, -1, and the two roots of the congruence $x^2 + 1 \equiv 0$, mod p, which we shall denote by $+f$ and $-f$, or by f and f^3, so that the four roots of $x^4 - 1 \equiv 0$ are $1, f, -1$, and f^3. Further, if k be any number prime to p, k satisfies one or other of the four congruences—

(i.) $k^{\frac{1}{4}(p-1)} \equiv 1$, mod p.	(iii.) $k^{\frac{1}{4}(p-1)} \equiv -1$, mod p.
(ii.) $k^{\frac{1}{4}(p-1)} \equiv f$, mod p.	(iv.) $k^{\frac{1}{4}(p-1)} \equiv f^3$, mod p.

We see therefore that the $p-1$ residues of p divide themselves into four classes, comprising each $\frac{1}{4}(p-1)$ numbers, according as they satisfy the 1st, 2nd, 3rd, or 4th of these congruences. The first class comprises those numbers a for which the congruence $x^4 \equiv a$, mod p, is resoluble; that is, the *biquadratic residues* of p; the third comprises those numbers which are quadratic, but not biquadratic, residues of p; the second and fourth classes divide equally between them the non-quadratic residues.

We owe to Gauss two memoirs* on the Theory of Biquadratic Residues, which, while themselves replete with results of great interest, are yet more remarkable for the impulse they have given to the study of arithmetic in a new direction. Gauss found by induction that a law of reciprocity (similar to that of Legendre) exists for biquadratic residues. But he also discovered that, to demonstrate or even to express this law, we must take into consideration the imaginary factors of which prime numbers of the form $4n+1$ are composed. By thus introducing the conception of imaginary quantity into arithmetic, its domain, as Gauss observes, is indefinitely extended; nor is this extension an arbitrary addition to the science, but is essential to the comprehension of many phenomena presented by real integral numbers themselves.

Gauss's first memoir (besides the elementary theorems on the subject) contains a complete investigation of the biquadratic character of the number 2 with respect to any prime $p=4n+1$. The result arrived at is that if p be resolved into the sum of an even and uneven square (a resolution which is always possible in one way, and one only), so that $p=a^2+b^2$ (where we may suppose a and b taken with such signs that $a \equiv 1$, mod 4; $b \equiv af$, mod p), 2 belongs to the first, second, third, or fourth class, according as $\frac{1}{2}b$ is of the form $4n$, $4n+1$, $4n+2$, or $4n+3$. The considerations by which this conclusion is obtained are founded (see Art. 22 of the memoir) on the theory of the division of the circle, and we shall again have occasion to refer to them. In the second memoir Gauss developes the general theory already referred to, by which the determination of the biquadratic character of any residue of p may in every case be effected. The equation $p=a^2+b^2$ shows that $p=(a+bi)(a-bi)$, or that p, being the product of two conjugate imaginary factors, is in a certain sense not a prime number. Gauss was thus led to introduce *as modulus* instead of p one of its imaginary factors: an innovation which necessitated the construction of an arithmetical theory of complex imaginary numbers of the form $A+Bi$. The elementary principles of this theory are contained in the memoir in question; they have also been developed by Lejeune Dirichlet with great clearness and simplicity in vol. xxiv. of Crelle's Journal (pp. 295–319, sect. 1–9)†. The following is an outline of the definitions and theorems which serve to constitute this new part of arithmetic.

25. *Theory of Complex Numbers.*—The product of a number $a+bi$ by its conjugate $a-bi$ is called its *norm*; so that the norm of $a+bi$ is a^2+b^2; the norm of a (which is its own conjugate) is a^2. This is expressed by writing $N(a+bi)=N(a-bi)=a^2+b^2$; $N(a)=a^2$. If α and β be two complex num-

* Theoria Residuorum Biquadraticorum. Commentatio prima et secunda. (Gottingæ, 1828 and 1832, and in the Comm. Recent. Soc. Gott., vol. vi. p. 27 and vol. vii. p. 89.) The articles in the two memoirs are numbered continuously. The dates of presentation to the Society are April 5, 1825, and April 15, 1831.

† The death of this eminent geometer in the present year (May 5, 1859) is an irreparable loss to the science of arithmetic. His original investigations have probably contributed more to its advancement than those of any other writer since the time of Gauss; if, at least, we estimate results rather by their importance than by their number. He has also applied himself (in several of his memoirs) to give an elementary character to arithmetical theories which, as they appear in the work of Gauss, are tedious and obscure; and he has thus done much to *popularize* the theory of numbers among mathematicians—a service which it is impossible to appreciate too highly.

bers, we have evidently $N(\alpha)\times N(\beta)=N(\alpha\beta)$. There are in this theory four units, $1, i, -1, -i$, which have each of them a positive unit for their norm. The four numbers $a+bi, ia-b, -a-ib, -ia+b$ (which are obtained by multiplying any one of them by the four units in succession, and which consequently stand to one another in a relation similar to that of $+a$ and $-a$ in the real theory) are said to be *associated* numbers. These four associated numbers with the numbers respectively conjugate to them form a group of eight numbers (in general different), all of which have the same norm. These definitions are applicable whatever be the nature of the real quantities a and b. If a and b are both rational, the complex number is said to be rational; if they are both integers, $a+bi$ is a complex integral number. One complex integer α is said to be divisible by another β, when a third γ can be found such that $\alpha=\beta\gamma$. Adopting these definitions, we can show that Euclid's process for investigating the greatest common divisor of two numbers is equally applicable to complex numbers; for it may be proved that, when we divide one complex number by another, we may always so choose the quotient as to render the norm of the remainder not greater than one-half of the norm of the divisor*. If, therefore, we apply Euclid's process for finding the greatest common divisor to two complex numbers, we shall obtain remainders with norms continually less and less, thus at last arriving at a remainder equal to zero; and the last divisor will be, as in common arithmetic, the greatest common divisor of the two complex numbers. Similarly the fundamental propositions deducible in the case of ordinary integers from Euclid's theory are equally deducible from the corresponding process in the case of complex integral numbers. Thus, "if a complex number be prime to each of two complex numbers, it is prime to their product." "If a complex number divide the product of two factors, and be prime to one of them, it must divide the other." "The equation $ax-by=1$, where a and b are complex numbers prime to one another, is always resoluble with complex numbers x and y, and admits an infinite number of solutions," &c.

A prime complex number is one which admits no divisors besides itself, its associates, and the four units.

There are three distinct classes of primes in the complex theory:—

1. Real prime numbers of the form $4n+3$ (with their associates).
2. Those complex numbers whose norms are real primes of the form $4n+1$.
3. The number $1+i$ and its associates the norm of which is 2.

Instead of dividing numbers into even and uneven, we must here divide them into three classes, uneven, semi-even, and even, according as they are (1) not divisible by $(1+i)$; (2) divisible by $1+i$, but not by $(1+i)^2$; (3) divisible by $(1+i)^2=2i$, or, which is the same thing, by 2.

Of four associated uneven numbers, there is always one, and only one, such that b is even and $a+b-1$ evenly even. This is distinguished from the others as *primary*. Thus -7 and $-5+2i$ are primary numbers. A primary number is congruous to $+1$ for the modulus $2(1+i)$; whence it appears that the product of any number of primary numbers is itself a primary number. The conjugate of a primary is also primary. In speaking of uneven numbers, unless the contrary is expressed, we shall suppose them to be primary. This definition of a primary number is that adopted by Gauss (*l.c.* Art. 36), and after him by Eisenstein, and we shall adhere to it in this

* Since $\frac{a+bi}{c+di}=\frac{ac+bd}{c^2+d^2}+\frac{bc-ad}{c^2+d^2}i$; if p be the integral number nearest to $\frac{ac+bd}{c^2+d^2}$, and q that nearest to $\frac{bc-ad}{c^2+d^2}$, $p+qi$ is the quotient required.

Report. But Gauss has also suggested a second definition (which is for some purposes slightly more convenient), and which has been adopted by Dirichlet, who defines a primary uneven number to be one in which b is uneven, and $a\equiv 1$, mod 4. The object of singling out one of the four associated numbers is merely that it serves to give definiteness to many theorems. For example, the theorem that "every real number may be expressed as the product of powers of real primes in one way, and in one only," may be now transferred in an equally definite form to the complex theory, "Every complex number can be expressed in one way only in the form $i^m(1+i)^n \mathrm{A}^\alpha . \mathrm{B}^\beta . \mathrm{C}^\gamma$ .... where m, n, α, β, γ, &c. are real integral numbers, A, B, C... *primary* complex primes."

If $a+bi$ be a complex number, and $\mathrm{N}=\mathrm{N}(a+bi)=a^2+b^2$, and if h be the greatest common divisor of a and b, it can be shown that every number is congruous, for the modulus $a+bi$, to one, and one only, of the numbers $x+iy$, where

$$x=0, 1, 2, \ldots. \frac{\mathrm{N}}{h}-1 \,; y=0, 1, 2, \ldots. h-1.$$

These numbers therefore (or any set of numbers congruous to them) form a complete system of residues for the modulus $a+bi$. The number of the numbers $x+iy$ is evidently N, so that the norm of the modulus represents the number of residues in a complete system. In particular, therefore, if the modulus $a+bi$ be a prime of the second kind, having p for its norm, the numbers $0, 1, 2, \ldots p-1$ represent a complete system of residues; and if the modulus be a prime of the first kind, as $-q$, the numbers included in the formula $x+iy$, where x and y may have any values from 0 to $q-1$ inclusive, will represent a complete system of residues.

26. *Fermat's Theorem for Complex Numbers.*—Dirichlet's proof of this theorem for ordinary integers is equally applicable to complex numbers, and leads us to the following result:—

"If p be a prime in the complex theory, and k any complex number not divisible by p, then $k^{\mathrm{N}p-1}\equiv 1$, mod p."

Again, the demonstration of the theorem of Lagrange (see Art. 11) is equally applicable here (see Gauss, Theor. Res. Biq., Art. 50), and therefore the general theorems mentioned in Art. 12 may be extended, *mutatis mutandis*, to the complex theory. In particular, the number of primitive roots will be $\psi[\mathrm{N}(p)-1]$, or the number of numbers less than $\mathrm{N}(p)-1$, and prime to it. It will follow from this that, if the modulus be an *imaginary* prime p, every primitive root of $\mathrm{N}p$ in the real theory will be a primitive root both of p and its conjugate. Those Tables of Indices, therefore, in the 'Canon Arithmeticus,' which refer to primes of the form $4n+1$ will continue to hold, if for the real modules we substitute either of the imaginary factors of which they are composed. For primes of the form $4n+3$ (considered as modules in the complex theory), it would be requisite to construct new tables, —a labour which no one as yet appears to have undertaken.

27. *Law of Quadratic Reciprocity for Complex Numbers.*—If p and q be any two uneven primes (not necessarily *primary*, but subject to the condition that their imaginary parts are even), and if we denote by $\left[\frac{p}{q}\right]$ the unit-residue of the power $p^{\frac{1}{4}[\mathrm{N}q-1]}$, mod q; so that $\left[\frac{p}{q}\right]=+1$, or $=-1$, according as p is or is not a quadratic residue of q: then a law of reciprocity exists, which is expressed by the equation $\left[\frac{p}{q}\right]=\left[\frac{q}{p}\right]$.

If p and q are both real primes, it is easily seen that either of them is a quadratic residue of the other in the complex theory, or $\left[\frac{p}{q}\right]=\left[\frac{q}{p}\right]=1$. But, as p may or may not be a quadratic residue of q in the theory of real integers, we see that the values of the symbols $\left[\frac{p}{q}\right]$ and $\left(\frac{p}{q}\right)$ are not necessarily identical.

This theorem is only enunciated in Gauss's memoir (Art. 60), and, as he speaks of it as a special case of the corresponding theorem for biquadratic residues, it is probable that his demonstration of it was of the same nature with that which he had found of the law of biquadratic reciprocity. However, a simple proof of it, depending on Legendre's law of reciprocity, has been given by Dirichlet in Crelle's Journal*. He shows that, if q be a prime of the first kind, $\left[\frac{\alpha+\beta i}{q}\right]=\left(\frac{\alpha^2+\beta^2}{q}\right)$; and that, if $a+bi$ be any prime of the second kind in which b is even, $\left[\frac{\alpha+\beta i}{a+bi}\right]=\left(\frac{a\alpha+b\beta}{a^2+b^2}\right)$. The law of reciprocity is easily deducible from these transformations. If, for example, $a+bi$, $\alpha+\beta i$, be primes of the second species in which both b and β are even, we have simultaneously

$$\left[\frac{\alpha+\beta i}{a+bi}\right]=\left(\frac{a\alpha+b\beta}{p}\right);\ \left[\frac{a+bi}{\alpha+\beta i}\right]=\left(\frac{a\alpha+b\beta}{\varpi}\right),$$

where $p=\mathrm{N}\,(a+bi)$; $\varpi=\mathrm{N}\,(\alpha+\beta i)$. But $\left(\frac{a\alpha+b\beta}{p}\right)=\left(\frac{p}{a\alpha+b\beta}\right)$, by Jacobi's formula (see Art. 17 *suprà*); and $\left(\frac{a\alpha+b\beta}{\varpi}\right)=\left(\frac{\varpi}{a\alpha+b\beta}\right)$. Also $p\varpi=(a\alpha+b\beta)^2+(a\beta-b\alpha)^2$; whence we infer $\left(\frac{p\varpi}{a\alpha+b\beta}\right)=1$, or, which is the same thing, $\left(\frac{p}{a\alpha+b\beta}\right)=\left(\frac{\varpi}{a\alpha+b\beta}\right)$; and therefore finally, $\left[\frac{\alpha+\beta i}{a+bi}\right]=\left[\frac{a+bi}{\alpha+\beta i}\right]$.

The complementary theorems which have to be united with this formula are

$$\left[\frac{i}{\alpha+\beta i}\right]=(-1)^{\frac{1}{4}(\varpi-1)};\ \left[\frac{1+i}{\alpha+i\beta}\right]=(-1)^{\frac{(\alpha+\beta)^2-1}{8}}$$

(see Dirichlet, Crelle, vol. xxx. p. 312); and they, as well as the formula of reciprocity itself, admit of an extension similar to that which Jacobi has given to the corresponding formulæ of Legendre.

28. *Reciprocity of Biquadratic Residues.*—We now come to the theorem which first suggested the introduction of complex numbers.

If p be any (complex) prime, and k be any residue not divisible by p, we denote by $\left(\frac{k}{p}\right)_1$ the power i^e of i, which satisfies the congruence $k^{\frac{1}{4}(\mathrm{N}p-1)}\equiv i$.

It will be observed that when p is a prime of the second species, the quadripartite classification of the real residues of p which we thus obtain is identical with that which we obtain for $\mathrm{N}p$ in the real theory (see Art. 24 *suprà*); for the numbers f and $-f$ being the roots of the congruence $x^2+1\equiv 0$, mod $\mathrm{N}p$,

* Crelle, vol. ix. p. 379.

satisfy the same congruence for either of the complex factors of Np, and are therefore congruous to $+i$ and $-i$, for one of those factors, and to $-i$ and $+i$ for the other. Admitting this definition of the symbol $\left(\frac{k}{p}\right)_4$, Gauss's law of biquadratic reciprocity is expressed by the equation

$$\text{(i.)}\ \left[\frac{\alpha}{\beta}\right]_4=(-1)^{\frac{1}{4}(\mathrm{A}-1)\cdot\frac{1}{4}(\mathrm{B}-1)}\left[\frac{\beta}{\alpha}\right]_4,$$

α and β denoting two primary uneven primes, and A and B being their norms.

The complementary theorems relating to the unit i and the semi-even prime $1+i$ are

$$\text{(ii.)}\ \left(\frac{i}{a+ia'}\right)_4=i^{-\frac{1}{2}(a-1)};\quad \text{(iii.)}\ \left(\frac{1+i}{a+ia'}\right)_4=i^{\frac{1}{4}\left((a+b-(1+b)^2\right)},$$

in which $a+ia'$ denotes a primary uneven prime. These formulæ, like those of the last article, are susceptible of the same generalization which Jacobi has applied to Legendre's symbol; and we may suppose in the first that α and β are any two primary uneven numbers, prime to one another; and in the second and third that $a+ia'$ is any primary uneven number.

If, in the formula (i.) which expresses the law of reciprocity, $\alpha=a+ia'$, $\beta=b+ib'$, it may be easily seen that the unit $(-1)^{\frac{1}{4}(\mathrm{A}-1)\frac{1}{4}(\mathrm{B}-1)}$ is equal to $(-1)^{\frac{1}{2}(a-1)\frac{1}{2}(b-1)}$. This gives us a second expression of the theorem. (See Eisenstein, Math. Abhandl. p. 137, or Crelle, vol. xxx. p. 193.)

Further, if we observe that every primary number is either $\equiv 1$, mod 4, or else $\equiv 3+2i$, mod 4; and that $\frac{1}{4}(\mathrm{A}-1)\frac{1}{4}(\mathrm{B}-1)$ and $\frac{1}{2}(a-1)\frac{1}{2}(b-1)$ are even numbers, except *both* α and β satisfy the latter congruence, we may enunciate the law of biquadratic reciprocity by saying—

"The biquadratic characters of two primary uneven prime numbers with respect to one another are identical, if either of the primes be $\equiv 1$, mod 4; but if neither of them satisfy that congruence, the two biquadratic characters are opposite."

This theorem is only enunciated by Gauss, who never published his demonstration of it. "Non obstante," he observes, "summâ huius theorematis simplicitate ipsius demonstratio inter mysteria arithmeticæ sublimioris maxime recondita referenda est, ita ut, saltem ut nunc res est, per subtilissimas tantum modo investigationes enodari possit, quæ limites præsentis commentationis longe transgrederentur."—Theor. Res. Biq. Art. 67.

Soon after the publication of the theorem, its demonstration was obtained by Jacobi, and communicated by him to his pupils in his lectures at Königsberg in the winter of 1836–37 (see his note to the Berlin Academy, already cited in Art. 17). These lectures have unfortunately never been published; but Jacobi's demonstration, from his criticism (see *ibid.*) on the first of those given ten years later by Eisenstein, appears to have been very similar to it.

It is to Eisenstein that we are indebted for the only published proofs of the theorem in question. That great geometer (so early lost to arithmetical science—a victim, it is said, to his devotion to his favourite pursuit) has left us as many as five demonstrations of it; the two earlier based on the theory of the division of the circle; the three last, on that of the lemniscate. We proceed to explain the principles on which each of these two classes of proofs depends:—

29. *Biquadratic Residues—Researches of* Eisenstein.—It is possible, as we have seen, to obtain a proof of Legendre's law of Reciprocity by considera-

tions relating to the function $\sum_{k=1}^{k=p-1} \left(\frac{k}{p}\right) x^k$, p denoting a real prime, and x a root of the equation $\frac{x^p-1}{x-1}=0$. This function is a particular case of the well-known function (introduced by Gauss and Lagrange into the theory of the division of the circle) $F(\theta, x)=\sum_{s=0}^{s=p-2} \theta^s x^{\gamma^s}$, where θ is *any* root of the equation $\frac{\theta^{p-1}-1}{\theta-1}=0$, γ a *primitive* root of the congruence $x^{p-1}\equiv 1$, mod p, and x a root of the equation $\frac{x^p-1}{x-1}=0$. In the quadratic theory we assign to θ the value -1; in the theory of Biquadratic Residues we put $\theta=i$, and are thus led to consider another particular form of the same function, viz. $F(i, x)=\sum_{s=0}^{s=p-2} i^s x^{\gamma^s}$, p denoting a prime of the form $4n+1$.

30. The function $F(\theta, x)$ or $F(\theta)$ is characterized by the following general properties; which have been given by Jacobi, Cauchy, and Eisenstein. (See Jacobi, Crelle, vol. xxx. p. 166; Cauchy, Mémoire sur la Théorie des Nombres in the Mém. de l'Acad. de l'Institut de France, vol. xviii.; Eisenstein, Crelle, vol. xxvii. p. 269.)

$$\text{I. } F(\theta, x^k)=\theta^{-\mathrm{Ind}\gamma^k} F(\theta, x),$$

$$\text{II. } F(\theta)\,F(\theta^{-1})=\theta^{\frac{p-1}{2}} p,$$

$$\text{III. } \frac{F(\theta^{-m})\,F(\theta^{-n})}{F(\theta^{-(m+n)})}=\psi(\theta),$$

where $\psi(\theta)$ does not involve x, and is an integral function of θ with integral coefficients*. The function $\psi(\theta)$ satisfies the equation

$$\text{IV. } \psi(\theta)\,\psi(\theta^{-1})=p.$$

Lastly, let θ be a *primitive* root of $\frac{x^{p-1}-1}{x-1}=0$, and in the function

$$\psi(\theta)=\frac{F(\theta^{-m})\,F(\theta^{-n})}{F(\theta^{-m-n})},$$

let γ be written for θ; then if m and n be positive and less than $p-1$,

$$\text{V. } \psi(\gamma)\equiv-\frac{\Pi(m+n)}{\Pi m\,.\,\Pi n}, \text{ mod } p;$$

Πm denoting the continued product $1.2.3\ldots m$.

Applying these equations to the particular form of the function F which we have to consider here, we find

$$F(i)\,F(-i)=i^{\frac{p-1}{2}} p,\ \psi(i)=\frac{F(i)\,F(i)}{F(-1)},\ \text{if } \theta^{\frac{1}{4}(p-1)}=i, \text{ and } m=n=\tfrac{3}{4}(p-1).$$

$$[F(i)]^4=p\psi(i)^2,$$

$$[F(-i)]^4=p\psi(-i)^2,\ \psi(i)\psi(-i)=p,$$

$$\psi(\gamma^{\frac{1}{4}(p-1)})\equiv 0, \text{ mod } p.$$

* In this equation θ^{-m} and θ^{-n} are supposed not to be reciprocals.

Let $\psi(i)=a+bi=p_1$; $\psi(-i)=a-bi=p_2$, so that $p_1p_2=p$. The congruence $\psi[\gamma^{\frac{1}{4}(p-1)}]\equiv 0$, mod p, or $a+b\gamma^{\frac{1}{4}(p-1)}\equiv 0$, mod p, involves also the congruence $a+b\gamma^{\frac{1}{4}(p-1)}\equiv 0$, mod p_1; *i. e.* $\gamma^{\frac{1}{4}(p-1)}\equiv i$, mod p_1; so that $\left(\frac{\gamma^k}{p_1}\right)_4=i^k$. Hence we have, putting $\gamma^s\equiv k$, mod p,

$$F(i)=\sum_{k=1}^{k=p-1}\left(\frac{k}{p_1}\right)_4 x^k=S,$$

$$F(-i)=\sum_{k=1}^{k=p-1}\left(\frac{k}{p_1}\right)_4^3 x^k=T.$$

From these formulæ two cases of the law of Reciprocity are directly deducible.

a. Let q be a real prime of the form $4n+3$. Raising S to the power q, we have

$$S^q\equiv\sum_{k=1}^{k=p-1}\left(\frac{k}{p_1}\right)_4^q x^{qk}\equiv\sum_{k=1}^{k=p-1}\left(\frac{k}{p_1}\right)_4^3 x^{qk}\equiv\left(\frac{q}{p_1}\right)_4 T, \text{ mod } q, \text{ by (I.)}.$$

Multiplying by S, we find

$$S^{q+1}=(S^4)^{\frac{q+1}{4}}=p^{\frac{q+1}{4}}p_1^{\frac{q+1}{2}}\equiv(-1)^{\frac{p-1}{4}}p\left(\frac{q}{p_1}\right)_4, \text{ mod } q;$$

or, observing that $p_2\equiv p_1^q$, mod q, and $p=p_1p_2$,

$$p_1^{\frac{q^2-1}{4}}\equiv(-1)^{\frac{p-1}{4}}\left(\frac{q}{p_1}\right)_4, \text{ mod } q;$$

that is to say, $$\left(\frac{p_1}{q}\right)_4=\left(\frac{-q}{p_1}\right)_4, \quad \ldots\ldots\ldots \quad \text{(A.)}$$

which is in accordance with the law of Reciprocity.

β. Again, let q be a prime of the form $4n+1$;

then $$S^q\equiv\left(\frac{q}{p_1}\right)_4^3 S, \text{ mod } q; \text{ that is, } S^{q-1}\equiv\left(\frac{q}{p_1}\right)_4^3, \text{ mod } q,$$

or $$p^{\frac{1}{4}(q-1)}p_1^{\frac{1}{2}(q-1)}\equiv\left(\frac{q}{p_1}\right)_4^3, \text{ mod } q;$$

whence, if $q=q_1q_2$,

$$\left(\frac{p_2}{q_1}\right)_4\left(\frac{p_1}{q_1}\right)_4^3=\left(\frac{q}{p_1}\right)_4^3.$$

But, by changing i into $-i$, $\left(\frac{p_1}{q_1}\right)_4^3=\left(\frac{p_2}{q_2}\right)_4$, and $\left(\frac{q}{p_1}\right)_4^3=\left(\frac{q}{p_2}\right)_4$,

so that $$\left(\frac{p_2}{q}\right)_4=\left(\frac{q}{p_2}\right)_4 \quad \ldots\ldots\ldots \quad \text{(B.)}$$

The symbolic equations (A.) and (B.) lead immediately to the conclusion that if a and b be any two primary uneven numbers, one, at least, of which is real, we have $\left(\frac{a}{b}\right)_4=\left(\frac{b}{a}\right)_4$; and that if a and b be both real, the common value of these symbols is $+1$. By combining with these results the supplementary equation $\left(\frac{i}{a+ia'}\right)_4 = i^{-\frac{1}{2}(a-1)}$, in which $a+ia'$ denotes any primary uneven number, and also the self-evident equations,

$$c(a \pm bi) = (ac+bd) \pm bi(c \pm di)$$
$$a(c \pm di) = (ac+bd) \pm di(a \pm bi),$$
$$\left(\frac{a+bi}{c+di}\right)_4 \left(\frac{a-bi}{c-di}\right)_4 = 1.$$

Eisenstein* investigates a relation between the symbols $\left(\frac{a+bi}{c+d}\right)_4$ and $\left(\frac{c+di}{a+bi}\right)_4$, which, when $a+bi$ and $c+di$ are primary, coincides with that expressed by the law of reciprocity.

31. The proof in Eisenstein's second memoir† is identical in its essential character with that in the first; but he has given it a purely arithmetical form, independent of the theory of the division of the circle. Instead of the sum $S = \sum_{k=1}^{k=p-1} \left(\frac{k}{p_1}\right)_4 x^k$, in which x is a root of the equation $\frac{x^p-1}{x-1}=0$, he considers the powers of the series $\sum_{k=1}^{k=p-1} \left(\frac{k}{p_1}\right)_4$, and arrives by a process purely arithmetical at the equations (A.) and (B.) of the preceding article. Thus the two forms in which he has exhibited his demonstration are precisely analogous to the two expressions which he has given to Gauss's sixth demonstration of Legendre's law (see above, Art. 21).

32. The proofs of the Law of Biquadratic Reciprocity, which are taken from the theory of elliptic functions, no less than those which we have just considered, depend in great measure on a generalization of the principles introduced by Gauss into his demonstrations of Legendre's law. Indeed, Gauss himself tells us‡ that his object in multiplying demonstrations of Legendre's law, was that he might at last discover principles equally applicable to the Biquadratic Theorem. It would be interesting to know whether the proof which he ultimately obtained of this theorem depended only on the division of the circle, or on elliptic transcendents. Jacobi appears to have believed the latter; for he expresses his opinion that his own demonstration of the Biquadratic Theorem was widely different from that of Gauss§; and he further conjectures that what induced Gauss to introduce complex numbers, *as modules*, into the theory of numbers, was not the study of any purely arithmetical question, but that of the elliptic functions connected with the Lemniscate Integral $\int \frac{dx}{\sqrt{(1-x^4)}}$‖. This opinion of Jacobi's will not appear im-

* See the memoir entitled "Lois de Réciprocité," in Crelle, vol. xxviii. pp. 53–67.

† "Einfacher Beweiss und Verallgemeinerung des Fundamental-Theorems für die biquadratischen Reste," in Crelle, vol. xxviii. p. 223.

‡ See the memoir, "Theorematis Fundamentalis Demonstrationes et Ampliationes Novæ," p. 4, "Hoc ipsum incitamentum erat ut demonstrationibus jam cognitis circa residua quadratica alias aliasque addere tantopere studerem, spe fultus, ut ex multis methodis diversis una vel altera ad illustrandum argumentum affine aliquid conferre posset."

§ "Ueber die Kreistheilung," Crelle, vol. xxx. p. 171.

‖ Crelle, vol. xix. p. 314, or in the 'Monatsbericht' of the Berlin Academy for May 16, 1839.

probable, when we remember that in the 'Disquisitiones Arithmeticæ' (Art. 335) Gauss promises an "amplum opus" on these transcendents; and that a casual remark of his in relation to them renders it perfectly certain (as Dirichlet has observed)* that he was at that early period in possession of the principle of the double periodicity of elliptic functions—thus anticipating by twenty-five years the discoveries of Abel and Jacobi. Nevertheless the close analogy we have endeavoured to point out between Gauss's sixth proof of the quadratic theorem, and the trigonometric demonstration of the biquadratic one, may perhaps incline us to the opposite opinion. Nor is the introduction of complex numbers, *as modules*, an idea unlikely to have suggested itself, when once complex numbers were admitted; though it is remarkable that Jacobi, in the first printed memoir in which complex numbers appear, and to which we shall presently refer, seems not to have thought of this extension of his theory.

33. *Application of the Lemniscate Functions to the Biquadratic Theorem*†.—Let p_1 be a complex prime (real or imaginary), p its norm; and let the $p-1$ residues, prime to p_1, be divided into four groups of $\frac{1}{4}(p-1)$ terms, after the following scheme:—

$$\begin{array}{lccccc}
(0) & r_1 & r_2 & \ldots\ldots\ldots\ldots & r_{\frac{1}{4}(p-1)}, \\
(1) & ir_1 & ir_2 & \ldots\ldots\ldots\ldots & ir_{\frac{1}{4}(p-1)}, \\
(2) & -r_1, & -r_2 & \ldots\ldots\ldots\ldots & -r_{\frac{1}{4}(p-1)}, \\
(3) & -ir_1, & -ir_2 & \ldots\ldots\ldots\ldots & -ir_{\frac{1}{4}(p-1)},
\end{array}$$

so that of any four *associated* numbers one, and only one, appears in each group. Let q_1 be any residue prime to p_1; $k_1, k_2, k_3, \ldots$ the numbers of the residues

$$q_1 r_1 \qquad q_1 r_2 \;\ldots\ldots\ldots\ldots\; q_1 r_{\frac{1}{4}(p-1)}$$

which belong to the groups (1), (2), (3), respectively; then

$$q_1^{\frac{1}{4}(p-1)} \equiv i^{k_1+2k_2+3k_3}, \text{ mod } p_1,$$

or

$$\left(\frac{q_1}{p_1}\right)_4 = i^{k_1+2k_2+3k_3}.$$

(See Gauss, Theor. Res. Biq. Art. 71.)

The expression on the right-hand side of this equation may now be transformed by means of the Lemniscate function ϕ, defined by the equations

$$v=\int_0^x \frac{dx}{\sqrt{(1-x^4)}}, \qquad x=\phi(v).$$

The function $\phi(v)$ is doubly periodic, the arguments of the periods being 2ω and $2i\omega$, or, more properly, $(1+i)\omega$ and $(1-i)\omega$, where $\frac{\omega}{2}=\int_0^1 \frac{dx}{\sqrt{(1-x^4)}}$; so that we have $\phi(v+2k\omega)=\phi(v)$, k denoting any complex integer whatever. From this it appears that the relation of the Lemniscate functions to the theory of complex numbers, is the same as the relation of circular func-

* In his 'Gedächtnissrede über Karl Gustav Jacob Jacobi,' Mém. de l'Académie de Berlin, 1852. This remarkable éloge is also inserted in Crelle's Journal, vol. lii., and in a French translation in Liouville's Journal, vol. ii. 2nd series.

† See Eisenstein's memoir, "Applications de l'Algèbre à l'Arithmétique transcendante," in Crelle's Journal, vol. xxx. p. 189, or in Eisenstein's 'Mathematische Abhandlungen,' p. 121.

tions to the arithmetic of real integers. The function $\phi(v)$ also satisfies the equation $\phi(i^k v)=i^k\phi(v)$, whence

$$i^{k_1+2k_2+3k_3}=\frac{\Pi\phi\left(\frac{2rq_1\omega}{p_1}\right)}{\Pi\phi\left(\frac{2r\omega}{p_1}\right)}=\left(\frac{q_1}{p_1}\right)_4, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.)$$

the sign of multiplication Π extending to every residue r included in the group (0). Similarly, if q_1, like p_1, be a prime,

$$\left(\frac{p_1}{q_1}\right)_4=\frac{\Pi\phi\left(\frac{2sp_1\omega}{q_1}\right)}{\Pi\phi\left(\frac{2s\omega}{q_1}\right)}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2.)$$

s denoting the general term of a *quarter-system* of Residues for the modulus q_1.

By an elementary theorem in the calculus of Elliptic Functions, $\frac{\phi(kv)}{\phi(v)}$ is for every uneven value of k a rational and fractional function of $x=\phi(v)$. If p_1 be primary, as we shall now suppose, and if we put $\alpha_r=\phi\left(\frac{2r\omega}{p_1}\right)$, we have, by the principles of that calculus,

$$\frac{\phi(p_1v)}{\phi(v)}=\frac{\Pi(x^4-\alpha^4)}{\Pi(1-\alpha^4x^4)}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3.)$$

the sign Π extending to all the different values of α_r; and similarly,

$$\frac{\phi(q_1v)}{\phi(v)}=\frac{\Pi(x^4-\beta^4)}{\Pi(1-\beta^4x^4)}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4.)$$

if $\beta_s=\phi\left(\frac{2s\omega}{q_1}\right)$. Combining the equations (3.) and (4.) with (1.) and (2.), we find

$$\left(\frac{q_1}{p_1}\right)_4=\frac{\Pi(\alpha^4-\beta^4)}{\Pi(1-\alpha^4\beta^4)}$$

$$\left(\frac{p_1}{q_1}\right)_4=\frac{\Pi(\beta^4-\alpha^4)}{\Pi(1-\alpha^4\beta^4)},$$

the sign of multiplication extending to the $\frac{1}{4}(p-1)(q-1)$ combinations of the values of α and β; whence, evidently,

$$\left(\frac{q_1}{p_1}\right)_4\left(\frac{p_1}{q_1}\right)_4=(-1)^{\frac{1}{4}(p-1)(q-1)}.$$

The priority of Eisenstein in this singularly beautiful investigation is indisputable.

34. In a later memoir (Beiträge zur Theorie der Elliptischen Functionen, Crelle, xxx. p. 185, or Math. Abhandl. p. 129), Eisenstein has put this proof into a slightly different form. He shows, by a peculiar method, that if p_1 be an *imaginary* and primary complex prime, every coefficient in $\Pi(x^4-\alpha^4)$ except the first is divisible by p_1, and that for every primary uneven value of p_1 (whether prime or not) the last coefficient is p_1, so that $(-1)^{\frac{1}{4}(p-1)}p_1=\Pi\alpha^4$.

Representing therefore by p_1 an imaginary and primary prime, by q_1 any complex prime, the equation

$$\left(\frac{p_1}{q_1}\right)=\Pi\frac{\phi\left(\frac{2sp_1\omega}{q_1}\right)}{\phi\left(\frac{2s\omega}{q_1}\right)}=\Pi\,\frac{\beta^4-\alpha^4}{1-\alpha^4\beta^4}$$

assumes the form $\left(\frac{p_1}{q_1}\right)\equiv(-1)^{\frac{1}{4}(p-1)(q-1)}\,q_1^{\frac{1}{4}(p-1)}$, mod p,

or $$\left(\frac{p_1}{q_1}\right)=(-1)^{\frac{1}{4}(p-1)(q-1)}\left(\frac{q_1}{p_1}\right),$$

which establishes the law of Reciprocity for every case except that of two real primes, when the value of the symbols $\left(\frac{p_1}{q_1}\right)_4=\left(\frac{q_1}{p_1}\right)_4=1$ is at once apparent from their definition and from Fermat's Theorem.

35. A third, and no less interesting application of the theory of elliptic functions to the formula of Biquadratic Reciprocity, occurs in the memoir, "Genaue Untersuchung der Unendlichen Doppel-Producte, aus welchen die Elliptische Functionen als Quotienten zusammengesetzt sind" (Mathematische Abhandl, p. 213, or Crelle's Journal, vol. xxxv. p. 249). The elliptic function

$$F(x)=\prod_{n=-\infty}^{n=+\infty}\prod_{m=-\infty}^{m=+\infty}\left(1-\frac{tx}{m+ni}\right),$$

which is considered in this memoir, and in which the factor $1-\frac{tx}{0}$ is to be replaced by tx, coincides (if we disregard a constant factor) with the numerator of $\phi(v)$, when that function is expressed as the quotient of one infinitely continued product divided by another. This may be seen by comparing $F(x)$ with the expression of the *general* elliptic function $\phi(\alpha)$ given by Abel, viz.

$$\phi(\alpha)=\prod_{\mu=1}^{\mu=\infty}\left(1+\frac{\alpha^2}{\mu^2\varpi^2}\right)\prod_{\mu=1}^{\mu=\infty}\left(1-\frac{\alpha^2}{m^2\omega^2}\right)$$
$$\times\prod_{m=1}^{m=\infty}\prod_{\mu=1}^{\mu=\infty}\left[\frac{1+\frac{(\alpha+m\omega)^2}{\mu^2\varpi^2}}{1+\frac{[\alpha+(m-\frac{1}{2})\omega]^2}{(\mu-\frac{1}{2})^2\varpi^2}}\cdot\frac{1+\frac{(\alpha-m\omega)^2}{\mu^2\varpi^2}}{1+\frac{[\alpha-(m-\frac{1}{2})\omega]^2}{(\mu-\frac{1}{2})^2\varpi^2}}\right]$$
$$\times\left[\frac{1+\frac{(m-\frac{1}{2})^2\omega^2}{(\mu-\frac{1}{2})^2\varpi^2}}{1+\frac{m^2\omega^2}{\mu^2\varpi^2}}\right]^2.$$

(See Abel, Œuvres, vol. i. p. 213, equat. 178.)

If we particularize this expression, by putting $\omega=\varpi$ (which changes $\phi(\alpha)$ into the Lemniscate-function) and then write $\cot x$ for α, we shall find that the function of x which appears in the numerator is precisely Eisenstein's function $F(x)$. This function (which is, consequently, a particular case of Jacobi's function H in his 'Fundamenta Nova') is only singly periodic; so that $F(x)=F\left(x+\frac{2\mu}{t}\right)$, if μ denote any real integer; but $F\left(x+\frac{2\mu}{t}\right)$ is equal to the product of F(x) by an exponential function, if μ be an *imaginary* complex number. (Compare the formulæ of sect. 61 of the 'Fundamenta Nova.') The difficulty occasioned by this imperfect periodicity of F(x) Eisenstein has overcome by the introduction of the number t, which is supposed to represent a real even indeterminate integer. The formulæ on which his proof depends, are

$$\text{(i)}\quad F(x+k)=\epsilon^{wt^2}F(x),$$

$$\text{(ii)}\quad F(ix)\quad =i\epsilon^{wt^2}F(x),$$

$$\text{(iii)}\quad \frac{F(p_1x)}{F(x)}=c^{p-1}\epsilon^{wt^2}\Pi.F\left(x+\frac{r}{p_1}\right).$$

The symbol w which depends on x, but is independent of t, is different in each of these equations: in the first, k is any complex integer; in the third, c is a numerical constant independent of x and p_1; p_1 a *primary* number prime to t; p its norm; and r the general term of the $p-1$ residues of p_1, the sign of multiplication Π extending to every value of r. These equations, the first two of which depend on the most elementary properties of the function F(x) or H (see 'Fundamenta Nova,' *loc. cit.*), while the third is of a more abstruse character, Eisenstein has established by methods which are peculiar to himself, and which it would take us too far from our present subject to describe. They serve to replace the formulæ

$$\phi(v)=\phi(v+2k\omega);\qquad \phi(iv)=i\phi(v);$$

$$\frac{\phi(p_1v)}{\phi(v)}=\frac{\Pi(x^4-\alpha^4)}{\Pi(1-\alpha^4x^4)}$$

in Eisenstein's earlier demonstration; and lead to the conclusion

$$\left(\frac{p_1}{q_1}\right)=\left(\frac{q_1}{p_1}\right)(-1)^{\frac{p-1}{4}\cdot\frac{q-1}{4}}\epsilon^{wt^2},$$

w still denoting some quantity independent of t. And since in this formula t may have any even value prime to p_1 and q_1, it is impossible that ϵ^w should have any value but that of one of the fourth roots of unity, so that we have $\epsilon^{wt^2}=1$; which gives the law of Reciprocity.

36. An algorithm has been given by Eisenstein* for calculating the value of the symbol $\left(\frac{a+ia'}{b+ib'}\right)_4$ by means of the development of $\frac{a+ia'}{b+ib'}$, in a continued fraction. This algorithm, in a slightly simplified form, is as follows:—Let $a+ia'=p_0$, $b+ib'=p_1$, and form the series of equations

$$p_0=k_0p_1\quad +i^{\mu_1}.p_2,$$

$$p_1=k_1p_2\quad +i^{\mu_2}.p_3,$$

$$\ldots\ldots\ldots\ldots\ldots\ldots$$

$$p_n=k_np_{n+1}+i^{\mu_{n+1}}.$$

The numbers p_0 and p_1 are supposed to be uneven, and prime to one another; p_1 is primary; the quotients $k_0, k_1, k_2 \ldots k_n$ are all divisible by $1+i$, and

* Crelle's Journal, vol. xxviii. p. 243. But the first invention of this algorithm, and of the similar one which exists in the Theory of Cubic Residues, is due to Jacobi. (See the note, "Ueber die Kreistheilung," &c., so often cited in this Report.)

are so chosen that the norms of $p_2, p_3 \dots$ form a continually decreasing series (as is always possible); lastly, the units i^{μ} are so chosen as to render $p_2, p_3 \dots$ primary. Let $p_s = a_s + i a_s$; let $-\frac{1}{2}(a_s - 1) \equiv \theta_s$, mod 4; and in the series $\theta_1, \theta_2 \dots \theta_{n+1}$, let ρ be the number of sequences of uneven terms. Then $\left(\frac{p_1}{p_2}\right)_4 = i^{2\rho + \Sigma\theta\mu}$.

Example. Let it be required to determine whether the congruence $x^4 \equiv -3381$, mod 11981 be possible or impossible.

Since $11981 = 109^2 + 10^2$, and is a prime number, the resolubility of this congruence depends on that of the congruence $x^4 \equiv -3381$, mod $(-109+10i)$. We have therefore to investigate the value of the symbol $\left(\frac{-3381}{-109+10i}\right)$. This gives us the series of equations

$$\begin{aligned}
-\ 3381 &= (31+3i)(-109+10i) + i^3(-17+28i),\\
-109+10i &= (2+2i)(-17+28i) + i^0(-19-12i),\\
-17+28i &= -2i\ (-19-12i) + i^0(+7-10i),\\
-19-12i &= -2i\ (7-10i) + i^2(-1-2i),\\
7-10i &= (3+5i)(-1-2i) + i.
\end{aligned}$$

Here $\theta_1 = -1$, $\theta_2 = +1$, $\theta_3 = 2$, $\theta_4 = 1$, $\theta_5 = 1$; so that $\rho = 2$, $\Sigma\mu\theta = 0$, and $\left(\frac{-3381}{-109+10i}\right)_4 = 1$, or the proposed congruence is resoluble. Its four roots are ± 87; ± 2646, as may be found by any of the indirect methods for the solution of Quadratic congruences.

37. *Cubic Residues.* The Theory of Cubic is less complex than that of Biquadratic Residues, and is at the same time so similar to it, that it will not be necessary to treat it with the same detail.

If p be a real prime of the form $3n+1$, and if $1, f, f^2$ denote the roots of the congruence $x^3 - 1 \equiv 0$, mod p, the $p-1$ residues $k_1, k_2 \dots k_{p-1}$ of p divide themselves into three classes according as $k^{\frac{1}{3}(p-1)} \equiv 1$, or $\equiv f$, or $\equiv f^2$, mod p; the first class comprising the cubic, the two other classes comprising the non-residues. Now it can be proved that every prime number of the form $3n+1$ may be represented by the quadratic form $A^2 - AB + B^2$; *i. e.* it may be regarded as the product of two conjugate complex numbers of the forms $A + B\rho$, $A + B\rho^2$, where ρ and ρ^2 are the two imaginary cube roots of unity; just as the theory of biquadratic residues involves the consideration of the quadratic form $A^2 + B^2$, and of complex numbers of the type $A + Bi$. The real integer $A^2 - AB + B^2$ is the *norm* of the complex numbers $A + B\rho$ and $A + B\rho^2$, and expresses the number of terms in a complete system of residues for either of those modules.

The theory of these complex numbers has not been treated of in detail by any writer (see Eisenstein, Crelle, vol. xxvii. p.290); but the methods of Gauss or Dirichlet are as applicable to them as to complex numbers involving i. Thus it will be found that every fraction of the form $\frac{A+B\rho}{C+D\rho}$ can be developed in a finite continued fraction, having for its quotients complex integers; that Euclid's process for finding the greatest common divisor is applicable in this case also, and that the same arithmetical consequences may be deduced from it as in the case of ordinary integers. The prime numbers to be considered in this theory are—

(1) Real primes, as 2, 5, 11, 17, &c. of the form $3n+2$.

(2) Imaginary primes of the form $A+B\rho$, having for their norms real primes of the form $3n+1$.

(3) The primes $1-\rho$, $1-\rho^2$, having 3 for their norm.

The units are ± 1, $\pm\rho$, and $\pm\rho^2$.

If $A+B\rho$ be any complex number not divisible by $1-\rho$, it may be seen that of the 3 pairs of numbers, $\pm(A+B\rho)$, $\pm\rho(A+B\rho)$, $\pm\rho^2(A+B\rho)$, there is always one, and one only, which, when reduced to the form $a+b\rho$, satisfies the congruences $a\equiv\pm 1$, $b\equiv 0$, mod 3. Such a number is called a primary number. The product of two primary numbers, taken negatively, is itself primary.

If α be any prime of this theory, and k any number not divisible by α, Fermat's Theorem is here represented by the congruence $k^{N\alpha-1}\equiv 1$, mod α.

Denoting by $\left(\frac{k}{\alpha}\right)_3$ that power ρ^s of ρ which satisfies the congruence $k^{\frac{1}{3}(N\alpha-1)}\equiv\rho^s$, the law of cubic reciprocity is contained in the formula

$$\left(\frac{\alpha}{\beta}\right)_3=\left(\frac{\beta}{\alpha}\right)_3,$$

α and β denoting any two *primary* complex primes.

The demonstration of this theorem follows quite naturally from the formulæ cited in Art. 30. Applying them to this particular case, we have, if p denote a real prime of the form $3n+1$,

$$\begin{aligned}
&\text{(i)} && F(\rho)\cdot F(\rho^2)=p,\\
&\text{(ii)} && [F(\rho)]^3=p\psi(\rho),\\
&\text{(iii)} && \psi(\rho)\cdot\psi(\rho^2)=p,\\
&\text{(iv)} && \psi(\gamma^{\frac{1}{3}(p-1)})\equiv 0, \text{ mod } p;
\end{aligned}$$

from which we may infer that $\gamma^{\frac{1}{3}(p-1)}\equiv\rho$, mod $\psi(\rho)$. (Compare Art. 29.) In the equation (iii), $\psi(\rho)$ and $\psi(\rho^2)$ are primary; for from the equation $[F(\rho)]^3=p\psi(\rho)$, it appears that $\psi(\rho)\equiv -1$, mod 3. The congruence $\gamma^{\frac{1}{3}(p-1)}\equiv\rho$, mod $\psi(\rho)$, implies that $\left(\frac{\gamma^s}{\psi(\rho)}\right)=\rho^s$, whence if $\gamma^s\equiv k$, mod p,

$$F(\rho) = \sum_{k=1}^{k=p-1}\left(\frac{k}{p_1}\right)_3 x^k,$$

$$F(\rho^2)= \sum_{k=1}^{k=p-1}\left(\frac{k}{p_1}\right)_3^2 x^k;$$

where $p_1=\psi(\rho)$. By these formulæ the several cases of the theorem of reciprocity may be proved, as follows*:—

First, let q be a prime of the form $3n+2$. Then

$$[F(\rho)]^q \equiv \sum_{k=1}^{k=p-1}\left(\frac{k}{p_1}\right)_3^q x^{qk}, \text{ mod } q,$$

* Eisenstein in Crelle's Journal, vol. xxvii. p. 289. But in this, as in many of his earlier researches, Eisenstein had been anticipated more than ten years by Jacobi.

$$\equiv\left(\frac{q}{p_1}\right)_3 F(\rho^2),\ \mathrm{mod}\ q,$$

or
$$[F(\rho)]^{q+1}\equiv\left(\frac{q}{p_1}\right)_3 p,\ \mathrm{mod}\ q.$$

But also
$$[F(\rho)]^{q+1}=p^{\frac{q+1}{3}}p_1^{\frac{q+1}{3}};$$

so that
$$p^{\frac{q-2}{3}}p_1^{\frac{q+1}{3}}\equiv\left(\frac{q}{p_1}\right)_3,\ \mathrm{mod}\ q;$$

or raising each side of this congruence to the power $q-1$,

$$p_1^{\frac{q^2-1}{3}}\equiv\left(\frac{q}{p_1}\right)_3 \quad \text{or} \quad \left(\frac{p_1}{q}\right)_3=\left(\frac{q}{p_1}\right)_3.$$

Secondly, let q be a real prime of the form $3n+1$; we find

$$[F(\rho)]^q\equiv\left(\frac{q}{p_1}\right)_3^3 F(\rho),\ \mathrm{mod}\ q, \quad \text{or} \quad F(\rho)^{q-1}\equiv\left(\frac{q}{p_1}\right)_3^2,\ \mathrm{mod}\ q;$$

and also
$$[F(\rho)]^{q-1}=p^{\frac{q-1}{3}}\,p_1^{\frac{q-1}{3}}.$$

Hence $\left(\frac{p}{q_1}\right)_3\left(\frac{p_1}{q_1}\right)_3=\left(\frac{q}{p_1}\right)_3^2$, where q_1 is either of the complex factors of q;

or, observing that $\left(\frac{p_1}{q_1}\right)_3^2=\left(\frac{p_2}{q_2}\right)_3$, and $\left(\frac{q}{p_1}\right)_3^2=\left(\frac{q}{p_2}\right)_3$, we may write

$$\left(\frac{p_2}{q_1}\right)_3\left(\frac{p_2}{q_2}\right)_3=\left(\frac{q_1}{p_2}\right)_3\left(\frac{q_2}{p_2}\right)_3.$$

It is clear from this, that if we denote the four symbols $\left(\frac{p_1}{q_1}\right)_3$, $\left(\frac{p_1}{q_2}\right)_3$, $\left(\frac{p_2}{q_1}\right)_3$, $\left(\frac{p_2}{q_2}\right)_3$ by a_1, b_1, b_2, a_2 respectively, and the reciprocal symbols by a_1', b_1', b_2', a_2', we have the equations

$$a_1b_1=a_1'b_1', \quad a_1b_2=a_1'b_2', \quad a_1a_2=a_1'a_2'=1,$$
$$a_2b_1=a_2'b_1', \quad a_2b_2=a\,'b\,', \quad b_1b_2=b_1'b_2'=1,$$

which imply that $a^2=a^{2\prime}$, $b^2=b^{2\prime}$, &c., or, since $a, a', b, b', \ldots$ are cubic roots of unity,

$$\left(\frac{p_1}{q_1}\right)_3=\left(\frac{q_1}{p_1}\right)_3.$$

If p_1 and q_1 be *conjugate* primes, the preceding proof fails; but it is easily seen that in this case also

$$\left(\frac{p_1}{p_2}\right)_3=\left(\frac{p_2}{p_1}\right)_3.$$

Lastly, if p and q are both of the form $3n+2$, it follows from the definition of the symbols, and from Fermat's Theorem, that

$$\left(\frac{p}{q}\right)_3=\left(\frac{q}{p}\right)_3.$$

The complementary theorems* relating to the unit ρ and the prime $1-\rho$ (which are not included in the preceding investigation), are

$$\left(\frac{\rho}{p_1}\right)_3 = \rho^{\frac{1}{3}(\mathrm{N}p_1-1)} = \rho^{\alpha+\beta},$$

$$\left(\frac{1-\rho}{p_1}\right)_3 = \rho^{2\alpha};$$

where p_1 is a primary prime, and α and β are defined by the equality $p_1=3\alpha-1+3\beta\rho$.

Eisenstein has observed† that a demonstration of the law of cubic reciprocity, precisely similar to that analysed in Art. 33 of this Report, may be obtained by considering the integral $\int \frac{dx}{\sqrt{(1-x^3)}}$ and its inverse function, instead of the Lemniscate integral and Lemniscate function. He has not, however, entered into any details on this interesting subject (which is the more to be regretted, because there appears to be no published memoir treating specially of the integral $\int \frac{dx}{\sqrt{(1-x^3)}}$); although his latest proof of the Biquadratic Law (see Art. 35) has been exhibited by him in such a form as to extend equally to Cubic Residues, and even to residues of the sixth power.

38. The first enunciation of the law of Cubic Reciprocity is due to Jacobi, and the demonstration of it which we have inserted in the preceding article is doubtless the same with that which he gave in his Königsberg Lectures. In one of his earliest memoirs ("De residuis cubicis commentatio numerosa," Crelle, vol. ii. p. 66), which was composed after the announcement, but before the publication, of Gauss's memoirs on Biquadratic Residues, Jacobi had already arrived at two theorems relating to Cubic Residues, which involve the law of Reciprocity, and which he seems to have deduced from his formulæ for the division of the circle. But, as it had not occurred to Jacobi, at the time when this memoir was written, to introduce, as modules, instead of the prime numbers themselves, the complex factors of which they are composed, the law of Cubic Reciprocity in its simplest form does not appear in the memoir.

To complete the present account of the Theory of the Residues of Powers, or of Binomial congruences, we should have in the next place to review the recent investigations of M. Kummer on complex numbers, and on the reciprocity of the residues of powers of which the index is a prime. But the consideration of these investigations, as well as of the other researches belonging to our present subject, our limits compel us to postpone to the second part of this Report.

* Eisenstein, Crelle's Journal, vol. xxviii. p. 28 (the continuation of the memoir cited in the preceding note).

† In the memoir, "Application de l'Algèbre," &c., already referred to.

Report of the Committee on Steam-ship Performance.

At the last Meeting of the British Association, held at Leeds, September 1858, this Committee was appointed, on the recommendation of the Mechanical Section, and the following Resolution was passed, defining the nature of the objects submitted to their investigation:—

"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 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:"—

Vice-Admiral Moorsom.
The Marquis of Stafford, M.P.
The Earl of Caithness.
Lord Dufferin.
Sir James Graham, Bart., M.P.
W. Fairbairn, F.R.S.
J. S. Russell, F.R.S.
J. Kitson, C.E.
W. Smith, C.E.
J. E. M'Connell, C.E.
Charles Atherton, C.E.
Professor Rankine, LL.D.
J. R. Napier, C.E.
Henry Wright, *Secretary*.

Your Committee, having elected Vice-Admiral Moorsom to be their Chairman, beg leave to present the following Report:—

They have held regular monthly meetings. Intermediate meetings of a Sub-committee, presided over by the Chairman, for the purpose of carrying out matters of detail submitted to them by resolutions passed at the general meetings, have also been held.

Your Committee deemed it advisable, at an early stage of the inquiry, to call to their aid the following noblemen and gentlemen, owners of steam-yachts, and others, who have rendered valuable assistance:—

C. R. M. Talbot, Esq., M.P.
G. Bentinck, Esq., M.P.
Lord Hill.
Lord Clarence Paget, M.P.
The Hon. A. Ellis, M.P.
Lord John Hay, M.P.
The Hon. Capt. Egerton, R.N.
Admiral Paris, of the Imperial Navy of France.

Not being Members of the British Association, however, they lent their assistance as corresponding members of the Committee.

The first object your Committee had in view was to obtain exact experimental data of such a nature as should appear likely to promote improvement in the construction and performances of steam-vessels.

With this view they furnished to members of Yacht Clubs, to Ship-owners, to Ship-builders, and Engineers, and to some of the large Steam-ship Companies, a Circular and Form of Return to be filled up with the particulars of the trial performances of their vessels.

The Return was intended to contain such particulars of the trials in smooth water at the measured mile, as it is usual to obtain for the satisfaction of the designer of the vessel and the builder of the engines. The Committee believe that *authenticated facts* recorded in this form would materially aid the scientific naval architect and the practical ship-builder, together with the engineer, in determining many elements which are at present held as opinions only, and about which considerable differences prevail. By obtaining the particulars of the sea performances of the same vessels, means would be thus afforded of making such comparisons with the smooth-water performances as could not fail to throw light upon qualities of vessels which, as yet, are matter of speculation only.

Your Committee, conceiving it very desirable, if possible, to obtain the cooperation of the Admiralty, presented a memorial to the First Lord, setting forth that, in the opinion of the Committee, it would be conducive to the advancement of science, the improvement of both vessels and engines, and to the great advantage of Her Majesty's service, if the trials of the Queen's ships were conducted on a more comprehensive plan, directed to definite objects of practical utility, on a scientific basis, and recorded in a uniform manner, and that the Committee believe that exact experiments and scientific records of performances, such as they are now contemplating, would lay the foundation of improvements in naval architecture, so that for the future it would be practicable to build ships, whether for the Royal Navy or for the Merchant Service, possessing high speed, great capacity, small draught of water, economy of power, and all the qualities which constitute a good sea-going ship, with much greater certainty than heretofore; and the Committee further stated that they were prepared, if desired, to conduct such experiments.

They also solicited an interview, in order that they might more fully explain their views.

A deputation, consisting of—

Admiral Moorsom,	The Hon. Capt. Egerton, R.N.,
The Marquis of Stafford, M.P.,	J. Scott Russell,
The Earl of Caithness,	J. E. M'Connell,
Lord John Hay, M.P.,	William Smith,
Lord Clarence Paget, M.P.,	Henry Wright,
The Hon. A. Ellis, M.P.,	

accordingly waited upon Sir J. S. Pakington, the late First Lord; and, in addition to the Memorial, they handed in a written statement, particularizing the nature of the experiments they considered desirable, together with the Circular and Form of Return for trial performances at the measured mile, which Form they suggested should be adopted by the Admiralty, instead of that already in use.

The deputation was favoured with an interview of considerable length, and the subjects brought forward were fully discussed. The result was that the First Lord admitted the great importance of the subject, and promised that the statements of the Committee should receive every consideration.

Political changes, however, having intervened, no steps had been taken for practically carrying their suggestions into effect, but your Committee have been informed that the consideration of the subject has been taken up by the present Administration.

Your Committee waited by deputation also on the Board of the Royal Mail Company, and after explaining their objects, and laying before the Board copies of the same documents as had been presented to the Admiralty, received the assurance that the Directors were willing and desirous to render every assistance, by furnishing all the information they possessed, as to the performance of the steam-vessels under their direction; and they have since furnished the trial data of the vessels fitted for sea since that date, as will be seen by the subjoined list of particulars communicated to this Committee.

The period, however, which has elapsed since the issue of the Circular and Form of Return being comparatively short, and the subject of scientific inquiry to mercantile men somewhat novel, the Committee feel that time is required to develope the interest, both in a commercial and a scientific point of view, which it so justly demands.

Your Committee have also been in communication with the Peninsular and Oriental Steam-ship Company, the West India Mail Company, and some large proprietors of steam-vessels, into whose hands they have placed the forms of return, and have received the assurance that, as opportunity offers, they shall be filled up and returned, in compliance with the Committee's request.

A communication was made on the subject to the American ambassador, and copies of the Circular and Form have been forwarded by him to his Government, with a request for such information as to the trials of the United States Government vessels as can be furnished.

Your Committee have given their attention to the question of *recording facts at sea.* Upon examining the different logs which have been laid before them, they found the particulars given so incomplete as to be unavailable for data upon which to base calculations for scientific improvement. To remedy this in future, they have, after careful examination and repeated discussion, agreed to a form of log to be filled up on actual sea service.

In arranging the particulars for the log, the Committee were materially assisted by very comprehensive forms transmitted by Admiral Paris, of the Imperial French Navy, and also by a letter from him, giving very circumstantial information on all the points to which scientific inquiry might be directed.

The object of it is to supply an authentic record of actual performance at sea, in order to compare it with the performance at the measured mile. It forms, in fact, a sequel to the returns proposed to be made on the test trials of vessels.

The Committee have had log-books* prepared for the use of steam-ship companies; and as they include all the useful particulars at present recorded in the ordinary ship's log, the Committee anticipate concurrence in its general adoption.

Accompanying the log-books are loose Return sheets, which the commander and engineer are invited to fill up from the log, and to return for the use of the Committee.

Your Committee beg to lay before the Association a statement of the result of their endeavours to obtain a record of the performances of steam-vessels.

The first is a complete set of returns of the performance of the Chester and Holyhead Company's steam-boats, plying between Holyhead and Kingstown, presented by Admiral Moorsom. They consist of—

I. 1. Return of the performances of the Chester and Holyhead Company's steam-vessels, under trial for a standard test.
2. Return of the speed and consumption of fuel of the steam-boats, under regulated conditions of time, pressure, and expansion, for given periods (1848 to 1850).
3. Return of the speed and consumption of coal of the express and cargo boats, under regulated conditions of time, pressure, and expansion, from January 31st, 1857 to 31st December, 1858.
4. Verification of consumption of coal, from January 1st, 1857 to December 31st, 1858.
5. Abstract of time of renewal of boilers, miles run, consumption of coals per mile, &c.
6. Return of shortest passages.
7. Return of mileage run, and expense per mile.

II. Return of particulars respecting the Chester and Holyhead Company's steam-vessels 'Anglia,' 'Cambria,' 'Scotia,' and 'Telegraph,' on their trials, filled in to the Committee's form of return.

III. 1. Return showing the result of experiments with the steam-yacht 'Undine' on the measured mile at Greenhithe, July 6th, 1858.
2. Ditto ditto, on passage from Holyhead to the Mull of Cantyre, July 29th and 30th, 1858.

* The log-book is arranged in precisely the same form as the return from Log. See Table opposite page 274.

3. Ditto ditto, in Loch Ness and Loch Lochy, October 26th and 27th, 1858.

IV. Return showing experiments with the steam-yacht 'Erminia,' in Stokes Bay, October 12th, 1858.

V. Return of particulars respecting the steam-ship 'Mersey,' whilst under trial. Furnished by the Royal Mail Company.

VI. Return of particulars respecting the steam-ship 'Paramatta,' whilst under trial. Furnished by the Royal Mail Company.

VII. Return of particulars respecting the steam-ship 'Lima,' whilst on trial between Liverpool and Dublin. Furnished by the Pacific Steam Navigation Company.

VIII. Return of particulars respecting the steam-ship 'Admiral,' whilst under trial. Recorded and furnished by Dr. Rankine.

IX. Return of particulars respecting the steamship 'Emerald.' Furnished by Mr. Thomas Steele, of Ayr.

Your Committee consider that it does not devolve upon them to institute any comparisons, or attempt to draw any conclusions, from the returns of performances laid before them.

Their duty is to collect information from authentic sources; but they do not hold themselves answerable for the facts with which they may be furnished.

The returns now made public will doubtless receive the notice of scientific and practical men, and the Committee anticipate benefits to science not less than to the commercial interests of the country, by the scrutiny which the facts stated will doubtless undergo by individuals engaged in these pursuits.

It is by the investigations of such persons that truth will be more satisfactorily brought out, and nature's laws vindicated, than by any attempt of the Committee in their collective capacity, but in which it is hoped individual members will bear their part; and when the caution which now naturally keeps back many from contributing their quota of information shall be removed by experience of the practical use of the labours of the Committee, and of their singleness of purpose, it may be expected that the materials of which the British Association will be the recipient, and which will be accessible to the world at large, will place what at present can only be called the art of ship-building, on the foundation of that pure science which acts in harmony with nature's laws.

The records of performance of Her Majesty's screw-vessels having been published subsequently to the commencement of the sittings of your Committee, they beg to express their sense of the wisdom of such a course, which they trust will be persevered in.

These records, in the form of a blue book, were well known to many, and Mr. W. Smith, C.E., a member of your Committee, had procured a copy for their use, which it was intended should be introduced into the Appendix of this Report, but which the publication renders now unnecessary.

These records are, however, incomplete as scientific data, as will be seen on comparing them with the form furnished to the Admiralty by your Committee.

In conclusion, the Committee recommend the re-appointment of a Committee, enlarging their powers to embrace returns relating to sailing ships, with a grant of money to enable them to collect information through their Secretary, and to defray the expenses of printing.

They cannot close this Report without expressing their best thanks to Mr. W. Smith, C.E., for the use of a room in his offices, and also for his kind liberality in printing and presenting to the Committee the circulars, forms, logs, returns, &c., here referred to.

They beg also thus to thank Mr. J. Yates for the kindness which enabled the Committee, at their early meeting, to avail themselves of the use of his room in Buckingham Street.

On behalf of the Committee,
C. R. Moorsom, Vice-Admiral, *Chairman.*

Office of the Committee,
19 Salisbury Street, Adelphi.

APPENDIX.

I.

Committee on Steam-ship Performance.

Adelphi, London, W.C., Feb. 23, 1859.

Sir,—I am requested by the Committee to submit for your consideration the following Circular, together with the enclosed form for return, any of the particulars of which, being authentic, the Committee will be glad to have.

Any further, or more circumstantial details which you may be pleased to give, the Committee will consider very valuable.

The object of the Committee being to lay the particulars thus obtained before the British Association at its next meeting, the Committee will esteem it a favour if you will give the matter your early attention.

I am, Sir, your very obedient Servant,
Henry Wright, *Secretary.*

Circular.

The British Association at its meeting at Leeds appointed a Committee to call the attention of proprietors of steam-vessels to the "great importance of adopting a general and uniform system of recording facts of performance of steam-vessels at sea under all circumstances, and to report to the Association at its next meeting."

The return (see Table 2, Appendix IV.) is intended to contain such particulars of the trials in smooth water at the measured mile as it is usual to obtain for the satisfaction of the designer of the vessel and the builder of the engines: and the Committee are aware that such particulars are usually confined to the knowledge alone of those persons.

It is, however, well known that information respecting these trial performances constantly appears in the newspapers, and that, not being authentic, and seldom furnishing all the requisite data, very erroneous conclusions are liable to be drawn from such statements.

The Committee believe that authenticated facts recorded in the form proposed would materially aid the scientific naval architect and the practical ship-builder, together with the engineer, in determining many elements which are at present held as opinions only, and about which considerable differences prevail.

The object of the Committee is to make public such recorded facts through the medium of the Association, and, being accessible to the public in that manner, to bring the greatest amount of science to the solution of the difficulties now existing to the scientific improvement of the forms of vessels and the qualities of marine engines.

They will especially endeavour to guard against information so furnished to them being used in any other way; and they trust they may look for the co-operation of Members of the Yacht Club having steam yachts, of ship-owners, as well as of builders and engineers.

The return of particulars of performance at sea will afford the means of making such comparisons with smooth-water performances as cannot fail to throw light upon qualities of vessels, which as yet are matter of speculation only.

The names of the Members of the Committee are annexed.

Vice-Admiral Moorsom, *Chairman*.

The Marquis of Stafford, M.P.
The Earl of Caithness.
The Lord Dufferin.
Sir James Graham, Bart., M.P.
William Fairbairn, F.R.S.
John Scott Russell, F.R.S.
James Kitson, C.E.
William Smith, C.E.
James E. M'Connell, C.E.
Charles Atherton, C.E.
Prof. Rankine, LL.D.
James R. Napier, C.E.
Henry Wright, *Secretary*.

II.

Memorial presented to the First Lord of the Admiralty.

The Memorial of the Committee of the British Association for the Advancement of Science, called "The Committee on Steam-ship Performance." To the Right Honourable Sir John S. Pakington, Bart., First Lord of the Admiralty,

Showeth—

That the Committee was appointed at the meeting of the British Association at Leeds in September last;

That their object is to obtain and make public through the Association authentic facts of the performance of steam-vessels, with the conditions and circumstances connected with such performances;

That they are aware that each steam-vessel of the Royal Navy undergoes a certain trial previous to being put in commission for service;

That a series of such trials from the year 1842 to 1850 was printed and circulated, by which the cause of science was advanced and the public service benefited;

That the Committee have also before them a second series of such trials up to the year 1856, which, though printed, has not, as the Committee believe, been yet made public;

That similar trials of vessels of the Merchant Service have been made since the first introduction of steam power, and are continued to this day;

That such trials being made for the satisfaction of private persons, have not been made public in any authentic form, and are not available for the advancement of science nor for the public benefit;

That the Committee have reason to believe that Steam-ship Companies, Ship-builders, and Engineers will give publicity to the trials of their vessels, through the instrumentality of the Committee, reasonable satisfaction being given that such use shall be made of the information as may conduce to advance science, and to the public benefit;

That it would tend to the advancement of science, the improvement of both vessels and engines, and to the great advantage of Her Majesty's Service, if the trials of the Queen's ships were conducted on a more comprehensive plan, directed to definite objects of practical utility on a scientific basis, recorded in a uniform manner;

That the Committee believe that exact experiments and scientific records of performance, such as they are now contemplating, would lay the foundation of improvements in Naval Architecture, so that for the future it would be practicable to build ships, whether for the Royal Navy or Merchant Service, possessing high speed, great capacity, small draught of water, economy of power, and all the qualities which constitute a good sea-going ship, with much greater certainty than heretofore, and the Committee are prepared to advise and, if desired, to conduct such experiments;

That the Committee solicit an interview with the First Lord of the Admiralty, at as early a day as may be convenient, for the furtherance of the objects herein stated. On behalf of the Committee,

(Signed) C. R. Moorsom, Vice-Admiral,

February 17, 1859. *Chairman.*

III.

Statement handed in to the First Lord of the Admiralty by the Deputation, particularizing the nature of the experiments which the Committee considered desirable should be made:—

1. Experiments showing the resistance, by dynamometer, to being towed through the water under the three following conditions:—
   The hull when launched.
   The hull with machinery on board.
   The hull when ready for sea.
2. Experiments to determine the actual measure of stability under the above conditions.
3. Experiments showing the resistance when propelled by steam under similar circumstances, both by indicator and dynamometer.

These experiments to be accompanied by the following particulars:—

1. The lines, dimensions, and ordinary elements of construction of the ship, such as displacement, dimensions, and tonnage, area of midship section, area at load water line, area of wet surface, &c., calculated measure of stability, and other elements of form.
2. Dimensions and number of boilers, grate surface, fire surface, tube surface, number, length, and diameter of tubes, and how disposed, number and dimensions of furnaces, &c., other elements of construction, regulation pressure, working pressure, &c.
3. Plan of engines, dimensions of cylinders, condenser, and air-pumps, description of valves, indicator diagrams, speed of piston, &c.
4. Propeller—nature and dimensions, condition of draught and immersion when working, measure of slip, propelling force by dynamometer, propelling power by indicator, &c.

IV. (See Tables 1 and 2 opposite.)

V.

Explanatory Statement to accompany the Returns relating to the Chester and Holyhead Company's Steam-vessels. (See Report, p. 268, and Tables 1 to 15 inclusive, Appendix V.)

For a full understanding of the Returns numbered 1 to 6, it is necessary to give such explanation as may enable any one to compare the purpose they were designed to serve with its fulfilment.

The heading under which each Return is noted in the schedule in some degree affords this explanation, but not altogether, and the following remarks will supply the deficiency.

When the four passenger vessels, 'Anglia,' 'Cambria,' 'Hibernia,' and 'Scotia' were first employed in August 1848, the commanders were authorized to drive them as hard as they could, subject only to the injunction not to incur danger*.

After some months' trial the qualities of each vessel and her engines were ascertained, and a system was brought into operation which continues to the present time. (Tables 3 to 15.)

The Returns No. 2 and No. 6 show the results of the *hard driving*, and of the commencement of *the system* periods. The column indicating "time," "pressure," and "expansion," is the key to the columns "average time of

* See Evidence before Select Committee of House of Commons, 1850 and 1853.

[*To face page* 274.]

APPENDIX IV.—TABLE 1. Return of particulars respecting the Steam-ship whilst under trial.

1–9	[illegible]
10	[illegible] ... ter, pitch, area or ... diameter ... boss
11	Depth of immersion from top of blade to ...
20	... under trial
35	Temperature of feed-water.
37	... contract.
40	The vacuum in condenser and external atmospheric pressure by gauges.
43	Dimensions of boiler.
44	Total weight of boil... water.
45	... in cubic feet.
46	Number of furnaces.
47	Dimensions of grate surface, tube surface, and ...
49	[illegible]
50	[illegible]
51	Actual area ...
53	Number, length, internal and external diameter and material of tubes.
54	Number and dimensions of chimneys.
55	Load on safety-valve.
56	Consumption of coal per hour.

APPENDIX IV.—TABLE 2. Return from Engineer's Log.

Steam Ship ______ ______ and ______ Day of ______, 18 ______.

Date.	Latitude.	Longitude.	...	Force	...	Height.	Direction.	...	Indicated H. P. with diagrams. When diagrams cannot be given, state proportion cut off in the cylinder	...	Average pressure of steam on piston.	...	Density of water in boiler.	How often blown off	...	Number of furnaces in work.	Area of grate surface	Area of tube surface.	Area of plate surface.	Consumption of coal. State description of coal.	...	Speed under sails and steam combined	Speed under sails ...	Draught of Water On Leaving Port. Fore	Aft.	On Arriving in Port. Fore	Aft.	Remarks.

NOTE.—The object of this Return is ... record of actual performance at sea ... the performance at the measured mile. It must be left to the judgment of the Commander and the Engineer under what circumstances ... ship, wind, weather, sea, current, &c., may ... It is to be understood that whatever can be tested instrumentally ... estimated according to experience.

The form ... any current ... twenty-four hours ... of them ... period embraced in the performance. The Commander and the Engineer are therefore invited ...

APPENDIX V. (*continued*). TABLE 1. Return of the performance of the Chester and Holyhead Company's Steam-vessels, under trial for a standard test.

Names of Vessels	Cylinders: Diameter	Cylinders: Length of Stroke	Cylinders: Number	Cylinders: Strokes per minute	Steam Pressure: On Piston, lbs. per square inch	Steam Pressure: In Boilers, lbs. per square inch	Weight per [illegible] Safety Valve	Barometer [illegible]	Hydrometer [illegible]	Nominal Horse-power	Area of Heating Surface: Tubes	Area of Heating Surface: Furnaces	Number of Boilers	Paddles: Diameter	Paddles: Effective Diameter	Floats: Breadth	Floats: Depth	Floats: Dip	Revolutions per minute	Load Water Line: Length	Load Water Line: Breadth	Mean Draught [illegible]	Mid-Section Area in square feet	Displacement in tons	Speed in Statute Miles per Hour: Trial in Smooth Water	Travel of Wheel between Holyhead & Kingstown in Statute Miles	Slip of Wheel [illegible] Statute Miles	Consumption of Coal in lbs. per Hour: Trial in Smooth Water	Indicator h.p. giving the speed as before: Trial in Smooth Water
	in.	ft. in.												ft. in.	ft. in.	ft. in.	ft. in.	ft. in.		ft. in.	ft. in.	ft. in.							
Anglia	45½	4 6	4	30	7 25	[illegible]	[illegible]	[illegible]	1 0	[illegible]	[illegible]	136	2	24 0	22 4	9 0	1 8	[illegible] 9	[illegible]	[illegible] 0	26 3	9 0	[illegible]	[illegible]	5 40	[illegible]	10½	76	[illegible]
Cambria	73½	5 0	3	40	4 25	1	5	[illegible]	[illegible]	[illegible]	[illegible]	450	1	28 0	27 0	7 [illegible]	4 [illegible]	5 10	[illegible]	[illegible] 9	[illegible]	8 1½	[illegible]	[illegible]	14 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Scotia	52	4 6	4	[illegible]	7 [illegible]	15	15	[illegible]	1 7	[illegible]	[illegible]	256	2	34 6	[illegible] 4	[illegible]	[illegible]	6 0	31	[illegible]	[illegible]	8 10	[illegible]	[illegible]	15 [illegible]	61½	9½	[illegible]	[illegible]
[illegible]	[illegible]	5 6	2	[illegible]	7 00	14	14	30	[illegible]	[illegible]	[illegible]	152	[illegible]	[illegible]	25 6	10 [illegible]	[illegible]	[illegible]	2	[illegible]	[illegible]	9 8	[illegible]	173	15 53	[illegible]	[illegible]	[illegible]	[illegible]

Deduct about 13 cwt. as the proportion per hour of consumption of coal for getting up steam, banking fires, &c.

APPENDIX V. (*continued*).—TABLE 2. Copy of a Return laid before a Select Committee of the House of Commons. See Blue Book on Dublin and Holyhead Mail Service, 1853, Appendix, p. 176. A Return of the Speed and Consumption of Fuel of the Steam-boats under regulated conditions of Time, Pressure, and Expansion, for the undermentioned periods.

Name of Boat	Date	Number of Trips of 63 Statute Miles, 64 0 Nautical	Time of Passage: Longest	Time of Passage: Shortest	Time of Passage: Average	Average rate of Speed in Statute Miles	Weight on Safety Valves: Greatest	Weight on Safety Valves: Least	Proportion of Steam in Cylinders	Coal: Supplied	Coal: Consumption	Orders under which each Vessel was directed to use the Elements of Time, Pressure, and Expansion
										Tons.	Tons. cwt. lbs.	
Anglia	1 Aug. to 31 Dec. 1848	76	5·20	4·25	2·59	15 8	19	11	[illegible] to ¾	1161¼	15 5 [illegible]	Time a minimum, pressure a maximum, expansion a minimum.
	1 Jan. to 30 June 1849	68	6 58	3 21	4 14	14 8	13	15	[illegible] to ¾	963	11 3[illegible]	Time a constant, pressure a constant, expansion according to tide, wind, and weather
	1 July to 31 Dec. 1849											
	1 Jan. to 31 Mar. 1850	31	5 29	4 6	4 31	13·9	17 4	13 2	[illegible] to [illegible]	337	10 10 3[illegible]	Time a constant, pressure expansion according to tide, wind and weather
Cambria	1 Aug. to 31 Dec. 1848	56	7 0	4 5	4 28	14 1	14	12	[illegible] to [illegible]	1457	10 3 [illegible]	Time a minimum, pressure a constant, expansion a constant
	1 Jan. to 30 June 1849	149	6·10	4 5	4 30	14	12	12	[illegible] to [illegible]	2203¼	14 16¼ 0	Time a constant.
	1 July to 31 Dec. 1849	89	6 11	3 57	4 25	14 2	11	12	[illegible] to [illegible]	1044	13 1 0	Pressure expansion according to wind, tide, and weather
	1 Jan. to 31 Mar. 1850	61	[illegible]	4 0	[illegible]	12 [illegible]	14	12	[illegible]	712	12 6 2[illegible]	Time a constant, pressure a constant, expansion a constant
Hibernia	1 Aug. to 31 Dec. 1848	27	6·40	4·18	5·16	11·5	15	11	[illegible] to [illegible]	624¼	23 2[illegible]	Unable to accomplish the conditions imposed as to time except under very favourable circumstances.
	1 Jan. to 30 June 1849	25	6·38	4 13	5 0	12 2	14	11	[illegible] to [illegible]	571	18 16¼	
	1 July to 31 Dec. 1849	123	7 19	4 1[illegible]	4 [illegible]	[illegible] 4	15	12	[illegible] to [illegible]	1,07[illegible]	15 3[illegible]	
	1 Jan. to 31 Mar. 1850	23	6·22	4 30	5 10	12 1	15	15	[illegible] to [illegible]	[illegible] 30	18 5[illegible]	
Scotia	1 Aug. to 31 Dec. 1848	6[illegible]	6 15	[illegible]	3 [illegible]	15 5	19	10¾	[illegible] to [illegible]	1[illegible]	17 3 1[illegible]	Time a minimum, pressure expansion according to tide, wind, and weather
	1 Jan. to 30 June 1849	59	7 38	3 21	4 0	1[illegible] 1	19	10[illegible]	[illegible] to [illegible]	932	15 15[illegible]	Time a constant, pressure expansion according to tide, wind, and weather
	1 July to 31 Dec. 1849	10[illegible]	6 19	[illegible]	4 [illegible]	13 3	1[illegible]	5¼	[illegible] to [illegible]	11[illegible] 4	13 4[illegible]	
	1 Jan. to 31 Mar. 1850	35	6 12	4 0	4 [illegible]	14·06	10¾	10[illegible]	[illegible] to [illegible]	472	13 9 2[illegible]	Time a constant, pressure expansion according to tide, wind, and weather

NOTE. The steam [illegible] during the period named were [illegible] Anglia, ranging between [illegible] and [illegible] lbs. Cambria [illegible] 12 lbs. [illegible] long[illegible] passages [illegible] The actual passages were not made in less time than four hours. [illegible] water [illegible] Cambria, [illegible]

passage," '[illegible]
and as a seq[illegible]
"Time a [illegible]
the system.
hard driving
speed the wi[illegible]
two element[illegible]
scribed limit[illegible]
The result[illegible]
The Retur[illegible]
ditions, but [illegible]
which result[illegible]
quarter's ret[illegible]
For examp[illegible]
lbs. of coal [illegible]
In the Ret[illegible]
the first at th[illegible]
about 409.
Again, in [illegible]
miles an hou[illegible]
Here was [illegible]
Return No. [illegible]
5820 lbs. pe[illegible]
that it becon[illegible]
being allowe[illegible]
No. 4 (se[illegible]
tween the is[illegible]
consumption[illegible]
No. 5 (se[illegible]
the work do[illegible]
with hard d[illegible]
justifiable a[illegible]
afterwards [illegible]
The 'Hi[illegible]
here observ[illegible]
power, it is [illegible]
The won[illegible]
whose cost [illegible]
the engines [illegible]
This defe[illegible]
and especi[illegible]
It would [illegible]
saving of c[illegible]
stores are c[illegible]
But the [illegible]
of economy[illegible]
Now it [illegible]
an establis[illegible]
authority n[illegible]
understand[illegible]
This has [illegible]
Hirste, mu[illegible]
carried out[illegible]
March 8, [illegible]

passage," "weight on safety-valves," and "proportion of steam in cylinder," and as a sequence also to the consumption of coal.

"Time a minimum" shows the *hard driving.* "Time a constant" shows *the system.* The relations of "pressure" and "expansion" show how, under *hard driving,* the highest pressure and the full cylinder produced the highest speed the wind and tide admitted; or how, the time being a constant, those two elements were varied at the discretion of the commander, within prescribed limits, to meet the conditions of wind and tide.

The result of the *system* on the coal is a decreasing consumption.

The Return No. 1 shows the results of certain trials under favourable conditions, but in the performance of the daily passage, by four of the vessels, which results are used as the standard tests with which the results of each quarter's returns are compared.

For example, the 'Scotia' at 15·9 statute miles an hour, consumes 6840 lbs. of coal as a standard. (See Table 4.)

In the Return No. 3, at the speed of 12·96 miles, she consumed 5226 lbs., the first at the rate of 430 lbs. per mile (see Table 5), and the second at about 403.

Again, in the succeeding quarter the 'Scotia' consumed 7528 lbs. at 14·65 miles an hour, or more than 513 lbs. per mile.

Here was a case for inquiry and explanation. It will be observed that in Return No. 1 the consumption of the 'Scotia' at ordinary work at sea is 5820 lbs. per hour; and it is only when the consumption exceeds 6840 lbs. that it becomes a subject of question, the difference between those figures being allowed for contingencies.

No. 4 (see Tables 12 and 13) is a Return which shows the difference between the issues of coal each half year, and the aggregate of the returns of consumption, the object of which needs no elucidation.

No. 5 (see Table 14) shows the duration of the boilers, with particulars of the work done. The saving in money under the return system as compared with hard driving was of course very considerable, and the latter was only justifiable as a necessary means of learning the qualities of each vessel, to be afterwards redeemed by the economy of *the system.*

The 'Hibernia,' it will be seen, was unequal to the service; and I may here observe, that experience has shown me that in machinery, as in animal power, it is essential that it should be considerably above its ordinary work.

The want of this extra power was a defect of the early locomotive engines, whose cost of working per mile was very considerably higher than that of the engines now in use.

This defect, which is that of boiler power, prevails largely in steam-vessels, and especially in the Queen's ships.

It would be easy to show how system *must* tend to economy; and the saving of coal is apparent from the returns, and of course all the engine stores are commensurate.

But the repairs, the wear and tear, involve a much more important element of economy than even a reduced consumption of coal.

Now it must be obvious that neither this nor any other attempt to bring an establishment like that at Holyhead under the supervision of a central authority at a distance, could be effectual without a perfect confidence and understanding between the parties.

This has happily subsisted for some years, and the Superintendent, Captain Hirste, must have the credit of having cordially entered into and faithfully carried out his instructions, for many of which he has furnished suggestions.

March 8, 1859. C. R. Moorsom.

APPENDIX V. (*continued*).—TABLE 3. CHESTER AND HOLYHEAD RAILWAY. STEAM-BOAT DEPARTMENT, 1857. A Return of the Speed and Consumption of Coal, under regulated conditions of Time, Pressure, and Expansion, for the undermentioned period.

Vessel.	Date.	No. of Trips run.	Time of Passage. Longest.	Time of Passage. Shortest.	Time of Passage. Average.	Average rate of Speed. Miles.	Actual Weight on Valves.	Average Pressure worked at.	Proportion of Steam in Cylinder.	Coals consumed. Per Trip, including getting up steam and while lying at Holyhead.	Coals consumed. Per Hour, inclusive of raising steam, banking fires, &c.	Coals consumed. Per Hour, exclusive of raising steam, banking fires, &c.
			h m	h m	h m		lbs.	lbs.		tons. cwt. lbs.	tons. cwt. lbs.	tons. cwt. lbs.
Anglia	1 Jan. to 31 March, 1857.	72	6 43	4 0	4 30	14·00	16	$11\frac{1}{3}$	$\frac{20}{36}$	13 3 77	2 18 66	2 5 105
Cambria......	Ditto	75	8 26	4 9	4 35	13·75	15	$14\frac{1}{2}$	$\frac{26}{36}$	13 0 12	2 16 84	2 3 9
Scotia	Ditto	7	5 23	4 32	4 52	12·96	14	$8\frac{1}{2}$	$\frac{15}{36}$	15 14 0	3 4 58	2 12 88
Telegraph ...	Ditto	Nil.										
Hibernia ...	Ditto	23	9 0	6 30	7 14	9·26	8	6	$\frac{13}{36}$ $\frac{15}{36}$ & $\frac{17}{36}$	13 7 0	1 16 102	1 8 69
Sea Nymph..	Ditto	54	8 26	5 0	5 58	11·24	14 & 12	11	1 & 2 gra.	12 1 41	2 0 50	1 10 81
Ocean	Ditto	71	16 25	6 20	7 36	8·81	10	$7\frac{4}{7}$	Nil.	11 3 42	1 9 43	1 4 43
Hercules ...	Ditto	28	9 30	6 0	7 12	9·30	8	$7\frac{5}{12}$	Nil.	9 9 56	1 6 35	1 2 17

Steam-Packet Office, Holyhead, 9th April, 1857. (Signed) WILLIAM STOREY.

TABLE 4.

Vessel.	Date.	No. of Trips run.	Longest.	Shortest.	Average.	Average rate of Speed. Miles.	Actual Weight on Valves.	Average Pressure worked at.	Proportion of Steam in Cylinder.	Per Trip, including getting up steam and while lying at Holyhead.	Per Hour, inclusive of raising steam, banking fires, &c.	Per Hour, exclusive of raising steam, banking fires, &c.
Anglia	1 April to 30 June, 1857.	61	5 5	4 0	4 20	14·52	16	12	$\frac{20}{36}$, none.	13 6 70	3 1 59	2 8 44
Cambria......	Ditto	76	4 57	4 8	4 28	14·13	15	15	$\frac{26}{36}$	12 15 24	2 17 15	2 3 96
Scotia	Ditto	17	4 33	4 3	4 18	14·65	15	12		14 9 6	3 7 24	2 13 106
	Special service.											
Telegraph ...	1 June to 30 June, 1857.	40 }	4 48	4 0	4 13	14·94	14	13	$\frac{21}{36}$, none.	13 13 70	3 4 99	2 11 15
Cambria......	On the 30th June, 1857.	2 }										
Hibernia ...	Nil.											
Sea Nymph..	1 April to 30 June, 1857.	83	7 22	5 5	6 0	11·06	12	$11\frac{1}{4}$	2d grade	10 14 6	1 15 75	1 6 1
Ocean	Ditto	61	10 40	5 55	7 12	9·53	10	$7\frac{1}{4}$	Nil.	10 5 30	1 8 57	1 3 25
Hercules ...	Ditto	44	8 0	5 50	6 42	10·14	8	7	Nil.	8 8 52	1 5 16	1 0 74

Steam-Packet Office, Holyhead, 24th July, 1857.

APPENDIX V. (*continued*).—TABLE 5.

Vessel.	Date.	No. of Trips run.	Time of Passage. Longest.	Time of Passage. Shortest.	Time of Passage. Average.	Average rate of Speed. Miles.	Actual Weight on Valves.	Average Pressure worked at.	Proportion of Steam in Cylinder.	Coals consumed. Per Trip, including getting up steam and while lying at Holyhead.	Coals consumed. Per Hour, inclusive of raising steam, banking fires, &c.	Coals consumed. Per Hour, exclusive of raising steam, banking fires, &c.
			h m	h m	h m		lbs.	lbs.		tons. cwt. lbs.	tons. cwt. lbs.	tons. cwt. lbs.
Anglia	1 July to 30 Sept. 1857.	98	4 52	4 5	4 25	14·22	16	$12\frac{3}{4}$	$\frac{20}{36}$, $\frac{23}{36}$, none	12 0 0	2 14 38	2 1 48
Cambria......	Ditto	58	5 20	4 9	4 29	14·19	15	15	$\frac{26}{36}$	12 8 46	2 15 0	2 2 0
Scotia	Ditto	56	5 28	4 1	4 20	14·53	15	$12\frac{3}{4}$	$\frac{18}{36}$, $\frac{21}{36}$, none	13 14 76	3 3 43	2 10 24
Telegraph ...	Ditto	78	6 15	4 5	4 24	14·31	14	$12\frac{1}{2}$	Nil.	16 7 7	3 14 27	3 1 15
Hibernia ...	Ditto	76	7 30	5 19	6 14	11·22	15	$8\frac{1}{2}$	Nil.	13 1 16	2 2 0	1 12 30
Hercules ...	Ditto	19	8 10	6 15	6 53	10·17	8	$7\frac{1}{2}$	Nil.	8 12 41	1 5 0	1 10 16
Ocean	Ditto	12	7 45	6 0	6 54	10·14	10	9	2 grade.	9 15 0	1 8 29	1 4 21
Sea Nymph..	Ditto	83	9 20	5 15	6 6	11·48	12	$11\frac{1}{2}$	full cylinder	9 13 0	1 11 71	1 2 14

TABLE 6.

Vessel.	Date.	No. of Trips run.	Longest.	Shortest.	Average.	Average rate of Speed. Miles.	Actual Weight on Valves.	Average Pressure worked at.	Proportion of Steam in Cylinder.	Per Trip	Per Hour, inclusive	Per Hour, exclusive
Anglia	1 Oct. to 31 Dec. 1857.	25	5 12	4 3	4 22	14·22	16	$13\frac{1}{4}$	$\frac{23}{36}$	12 5 0	2 16 11	2 3 6
Cambria......	Ditto	74	6 10	4 11	4 50	13·02	15	12	$\frac{26}{36}$	12 19 39	2 13 69	2 1 42
Scotia	Ditto	59	6 0	4 11	4 36	13·69	15	$11\frac{1}{2}$	$\frac{15}{36}$	12 15 81	2 15 48	2 3 4
Telegraph ...	Ditto	16	*6 55	*4 11	4 26 4 50	14·21	15	$11\frac{1}{2}$	$\frac{15}{36}$ $\frac{18}{36}$	13 12 0	2 6 30	2 4 10
Hibernia ...	Ditto	78	9 10	5 40	6 37	10·57	15	$7\frac{3}{4}$	$\frac{15}{36}$	14 6 56	2 3 25	1 14 102
Sea Nymph..	Ditto	74	11 30	5 15	6 48	10·26	12	11	2 grade	10 11 15	1 11 3	1 2 56
Ocean.........	Ditto	40	11 45	6 0	7 50	8·93	10	$8\frac{3}{4}$	full	10 11 55	1 6 104	1 2 38
Hercules ...	Ditto	Nil.										

* Slow speed, accident.

Correct from Returns in Office. (Signed) THOMAS HIRSTE.

Appendix V. (*continued*).—Table 7.

Vessel.	Date.	No. of Trips run.	Time of Passage. Longest.	Time of Passage. Shortest.	Time of Passage. Average.	Average rate of Speed. Miles.	Actual Weight on Valves.	Average Pressure worked at.	Proportion of Steam in Cylinder.	Coals consumed. Per Trip, including getting up steam and while lying at Holyhead.	Coals consumed. Per Hour, inclusive of raising steam, banking fires, &c.	Coals consumed. Per Hour, exclusive of raising steam, banking fires, &c.
			h m	h m	h m		lbs.	lbs.		tons. cwt. lbs.	tons. cwt. lbs.	tons. cwt. lbs.
Anglia	1 Jan. to 31 Mar. 1858.	72	7 0	4 0	4 36	13·69	16	13	$\frac{20}{36}$	12 10 14	2 14 27	2 1 101
Cambria......	Ditto	Nil.										
Scotia	Ditto	78	7 2	4 13	4 43	13·35	15	$12\frac{1}{2}$	$\frac{15}{36}$	13 3 81	2 15 92	2 3 83
Telegraph ...	Ditto	Nil.										
Hibernia ...	Ditto	76	9 0	5 47	6 40	10·50	15	7	$\frac{11}{36}$ $\frac{13}{36}$	13 15 100	2 1 41	1 13 14
Hercules ...	Ditto	28	12 0	6 5	7 35	9·23	12	11	Nil.	9 8 100	1 4 102	1 0 106
Ocean	Ditto	36	14 21	7 18	7 38	9·17	10	$8\frac{1}{2}$	Nil.	10 3 0	1 6 61	1 1 94
Sea Nymph..	Ditto	44	9 20	5 20	6 50	10·24	12	$10\frac{3}{4}$	2nd grade	10 12 71	1 11 7	1 2 66

Table 8.

Vessel.	Date.	No. of Trips run.	Time of Passage. Longest.	Time of Passage. Shortest.	Time of Passage. Average.	Average rate of Speed. Miles.	Actual Weight on Valves.	Average Pressure worked at.	Proportion of Steam in Cylinder.	Coals consumed. Per Trip, including getting up steam and while lying at Holyhead.	Coals consumed. Per Hour, inclusive of raising steam, banking fires, &c.	Coals consumed. Per Hour, exclusive of raising steam, banking fires, &c.
Express :—												
Anglia	1 April to 30 June, 1858.	59	8 1	4 5	4 34	13·79	16	$13\frac{1}{2}$	$\frac{20}{36}$	11 17 75	2 12 4	1 19 65
Cambria......	Ditto	40	4 42	4 12	4 24	14·31	15	15	$\frac{26}{36}$	12 1 23	2 14 91	2 1 38
Scotia	Ditto	55	5 37	4 12	4 34	13·79	15	$11\frac{1}{2}$	$\frac{15}{36}$, $\frac{18}{36}$	13 1 44	2 17 26	2 4 83
Telegraph ...	Ditto											
Cargo :—												
Hibernia ...	Ditto	75	8 45	5 45	6 19	11·08	15	$7\frac{3}{4}$	$\frac{13}{36}$	13 0 79	2 1 30	1 12 63
Hercules ...	Ditto	19	9 30	6 0	6 38	10·55	12	$10\frac{1}{4}$	Nil.	7 17 17	1 3 75	0 19 18
Ocean	Ditto	4	11 25	7 5	8 29	8·25	10	$8\frac{1}{2}$	Nil.	9 2 0	1 1 50	0 17 38
Sea Nymph..	Ditto	77	9 35	5 25	6 23	10·96	12	10	2nd grade	10 9 13	1 11 85	1 3 75

APPENDIX V. (*continued*).—TABLE 9.

Vessel.	Date.	No. of Trips run.	Time of Passage. Longest.	Time of Passage. Shortest.	Time of Passage. Average.	Average rate of Speed. Miles.	Actual Weight on Valves.	Average Pressure worked at.	Proportion of Steam in Cylinder.	Coals consumed. Per Trip, including getting up steam and while lying at Holyhead. tons.	cwt.	lbs.	Per Hour, inclusive of raising steam, banking fires, &c. tons.	cwt.	lbs.	Per Hour, exclusive of raising steam, banking fires, &c. tons.	cwt.	lbs.
			h m	h m	h m		lbs.	lbs.		tons.	cwt.	lbs.	tons.	cwt.	lbs.	tons.	cwt.	lbs.
Express:—																		
Anglia	1 July to 30 Sept. 1858.	13	5 25	4 24	4 36	13·69	16	14		12	12	94	2	14	108	2	2	66
Cambria......	Ditto	17	5 21	4 12	4 30	14·00	15	$13\frac{3}{4}$	$\frac{26}{36}$	12	6	27	2	14	80	2	1	60
Scotia.........	Ditto	Nil.																
Telegraph ...	Ditto	68	5 15	4 13	4 25	14·26	10	$8\frac{3}{4}$		13	11	82	3	1	58	2	8	43
Cargo:—																		
Hibernia ...	Ditto	67	8 15	5 55	6 28	10·82	15	$7\frac{1}{2}$	$\frac{13}{26}$	13	14	40	2	2	43	1	13	103
Hercules ...	Ditto	25	13 24*	6 10	7 4*	9·90	12	$10\frac{3}{4}$		8	2	22	1	2	106	0	18	79
Ocean	Ditto	20	9 50	6 25	7 16	9·63	10	$7\frac{3}{4}$		10	1	16	1	7	76	1	2	1
Sea Nymph..	Ditto	71	13 53*	5 35	6 31	10·74	12	$10\frac{1}{2}$	2nd grade	10	9	37	1	12	13	1	3	24

* Longest passage, detained by dense fog.

TABLE 10.

Vessel.	Date.	No. of Trips run.	Time of Passage. Longest.	Time of Passage. Shortest.	Time of Passage. Average.	Average rate of Speed. Miles.	Actual Weight on Valves.	Average Pressure worked at.	Proportion of Steam in Cylinder.	Coals consumed. Per Trip, including getting up steam and while lying at Holyhead. tons.	cwt.	lbs.	Per Hour, inclusive of raising steam, banking fires, &c. tons.	cwt.	lbs.	Per Hour, exclusive of raising steam, banking fires, &c. tons.	cwt.	lbs.
Express:—																		
Anglia	1 Oct. to 31 Dec. 1858.	22	6 16	4 4	4 40	13·50	15	13	$\frac{15}{36}$ $\frac{16}{36}$	13	0	76	2	15	96	2	3	74
Cambria......	Ditto	57	7 38*	4 11	4 37	13·64	15	$13\frac{1}{2}$	$\frac{26}{36}$	12	15	72	2	15	42	2	2	59
Scotia	Ditto	51	6 15	4 15	4 41	13·45	15	$11\frac{1}{2}$	$\frac{18}{36}$	13	14	19	2	18	60	2	6	41
Telegraph ...	Ditto	24	5 10	4 18	4 32	13·87	10	9		13	11	102	2	19	109	2	7	21
Cargo:—																		
Hibernia ...	Ditto	77	10 5†	5 30	6 42	10·44	15	$7\frac{1}{2}$	$\frac{13}{36}$ $\frac{15}{36}$ $\frac{17}{36}$	14	9	32	2	3	19	1	14	108
Hercules ...	Ditto	75	14 40†	6 0	7 29	9·35	12	$10\frac{3}{4}$		8	12	26	1	3	1	0	19	0
Ocean	Ditto	14	9 32	6 25	7 52	8·90	10	$8\frac{1}{2}$	2nd grade	11	1	8	1	8	11	1	3	58
Sea Nymph..	Ditto	77	13 5‡	5 30	6 53	10·16	12	10		10	13	68	1	11	3	1	2	67

* Cambria's longest passage, occasioned by a heavy easterly gale. † Longest passage, occasioned by a heavy easterly gale.
‡ Longest passage, occasioned by dense fog.

APPENDIX V. (*continued*).—TABLE 11. Consumption of Coal for the Six Months ending 30th June 1858.

Name of Vessel.	Period.	No. of Trips.	Average number of tons each trip. tons.	cwt.	lbs.	Total for the six months. tons.	cwt.	lbs.	Total as shown by General Account, including Coal on board. tons.	cwt.	lbs.	Remarks.
Anglia	3 Months to 31 Mar.	72	12	10	14	1601	11	57	1613	9	0	
	„ 30 June	59	11	17	75							
Cambria	„ 31 Mar.					482	8	24	505	18	0	
	„ 30 June	40	12	1	23							
Scotia	„ 31 Mar.	78	13	3	81	1747	7	2	1770	6	0	
	„ 30 June	55	13	1	44							
Telegraph	„ 31 Mar.											
	„ 30 June											
Hibernia	„ 31 Mar.	76	13	15	100	2021	19	77	2058	12	0	
	„ 30 June	75	13	0	79							
Hercules	„ 31 Mar.	28	9	8	100	413	14	99	441	11	0	
	„ 30 June	19	7	17	17							
Ocean	„ 31 Mar.	36	10	3	0	401	16	0	399	7	0	
	„ 30 June	4	9	2	0							
Sea Nymph	„ 31 Mar.	44	10	12	71	1272	17	93	1273	18	0	
	„ 30 June	77	10	9	13							
						7941	15	16	8063	1	0	

TABLE 12. Consumption of Coal for the Six Months ending 31st December, 1858.

Name of Vessel.	Period.	No. of Trips.	Average number of tons each trip. tons.	cwt.	lbs.	Total for the six months. tons.	cwt.	lbs.	Total as shown by General Account, including Coal on board. tons.	cwt.	lbs.	Remarks.
Anglia	3 Months to 30 Sept.	13	12	12	94	451	1	94	564	0	0	
	„ 31 Dec.	22	13	0	76							
Cambria	„ 30 Sept.	77	12	6	27	1676	12	23	1667	6	0	
	„ 31 Dec.	57	12	15	72							
Scotia	„ 30 Sept.					699	2	73	687	15	0	
	„ 31 Dec.	51	13	14	19							
Telegraph	„ 30 Sept.	68	13	11	82	1250	3	62	1229	4	0	
	„ 31 Dec.	24	13	11	102							
Hibernia	„ 30 Sept.	67	13	14	40	2032	16	104	2006	17	0	
	„ 31 Dec.	77	14	9	22							
Hercules	„ 30 Sept.	25	8	2	32	848	12	36	851	7	0	
	„ 31 Dec.	75	8	12	26							
Ocean	„ 30 Sept.	20	10	1	16	355	17	96	358	8	0	
	„ 31 Dec.	14	11	1	8							
Sea Nymph	„ 30 Sept.	71	10	9	37	1565	10	23	1568	11	0	
	„ 31 Dec.	77	10	13	68							
						8879	17	63	8933	8	0	

APPENDIX V. (*continued*).—TABLE 13. A Return showing the number of years run before the 'Anglia,' 'Cambria,' 'Scotia,' and 'Hibernia' had new Boilers, number of miles run, and consumption of Coal per mile, with and without raising Steam, banking Fires, lying at Kingstown and Holyhead, Steam Pressure in Boilers.

Name of Vessel.	Weight of Boilers.			Number of years run before receiving new Boilers.	Number of statute miles run.	Rate of speed per hour, statute miles.	Coals consumed per mile, including getting up steam, &c.			Coals consumed per mile in running only.			Mean Pressure per square inch in boilers.
	tons.	cwt.	lbs.				tons.	cwt.	lbs.	tons.	cwt.	lbs.	lbs.
Anglia	47	10	3	8½	113,166	14·61	0	3	82	0	2	97	12
Cambria	75	4	1	8	103,944	14·51	0	3	95	0	2	110	11
Scotia	51	6	1	8½	107,592	14·75	0	4	10	0	3	26	11¾
Hibernia, Express	45	5	0	8½	20,800	12·62	0	4	54	0	3	68	12
Hibernia, Cargo...	45	5	0	8½	78,225	10·31	0	3	37	0	2	66	8

The goods trade, time of passage limited to 6½ hours.

TABLE 14.—A Return of Passages made by the Steam-boats in 3½ hours, &c.

Name of Boat.	Date.	Time of		Length of Passages.	Valves, maximum at which set, or grades at which worked.	Steam-gauge or Indicator.		Expansion proportion in Cylinder.	Remarks.
		Departure from	Arrival at			Highest.	Lowest.		
	1848.	Kingstown	Holyhead	h m					
Anglia	25 Aug.	9·11 A.M.	0·44 P.M.	3 33					The forms of Engineer's logs in office are from Nov. 1848 only. The quantity of coals consumed per trip was not furnished at the period of these returns; but taking one year's average from 1st August 1848 to 31st July 1849, and after deducting for raising steam and banking fires, it would stand as follows: viz. Anglia.... 12 tons Scotia.... 14 ,, or as near as can be ascertained.
,,	1 Sept.	9·9 ,,	0·41 ,,	3 32					
,,	2 ,,	9·9 ,,	0·42 ,,	3 33					
		Holyhead	Kingstown						
,,	16 ,,	6·35 P.M.	10·0 P.M.	3 25	15	16	14	$\frac{3}{5}$	
		Kingstown	Holyhead						
Scotia	4 ,,	9·7 A.M.	0·41 P.M.	3 34					
		Holyhead	Kingstown						
,,	12 ,,	6·33 P.M.	10·6 P.M.	3 33					
		Kingstown	Holyhead						
,,	18 ,,	9·10 A.M.	0·38 P.M.	3 28					
	1849.	Holyhead	Kingstown						
,,	29 March	9·16 P.M.	9·40 P.M.	3 24	17	19	15	$\frac{4}{9}$	

APPENDIX V. (*continued*).—TABLE 15.

Mileage run, and expenses per mile, of the Passenger Boats in the years 1849, and 1856, 1857, 1858.

	1849.		1856.		1857.		1858.	
Miles run	39,910		40,885		52,910		40,040	
Expenses.	Total.	Per mile.	Total.	Per mile.	Total.	Per mile.	Total.	Per mile.
	£	s. d.	£	s. d.	£	s. d.	£	s. d.
Wages.....................	8,294	4 2	5,461	2 8	5,736	2 2	5,160	2 6¾
Coal	5,420	2 8½	5,554	2 8½	6,387	2 5	4,354	2 2
Engine Stores, Ship Stores, and Repairs	4,890	2 5½	3,517	1 8¾	3,592	1 4¼	2,540	1 3¼
Harbour Light Dues...	1,609	0 9½	321	0 2	431	0 2	318	0 2
General Charges	425	0 2½	595	0 3½	1,316	0 6	1,172	0 7
Total	20,638	10 4	15,448	7 6¾	17,462	6 7¼	13,544	6 9

VI.

*** The numbers in the Returns given below correspond with the numbers of the columns in the *Trial Form of Return.* (See Table opposite page 274.)

Return of Particulars respecting the Steam-ship 'Anglia' whilst under Trial.

1. Between Holyhead and Kingstown, six trips, 29th of September to 3rd of October, 1854. 2. W.S.W. to N.N.W.; fine, moderate; tides favourable. 3. 2 tons, 16 cwt., 102 lbs. 4. 12 tons, 13 cwt., 3 lbs. per trip. 5. Not ascertained. 6. 729·70 to 891·76. 7. Paddle. 8. See column 1. 9. See column 1. 10. 14·94 statute miles. 11. 187 ft. 10 in. 12. 186·25 square feet midsection. 13. 9 ft. 14. 620. 21. Diameter, 24 ft. 6 in.; length, 9 ft. 6 in.; breadth, 3 ft. 8 in.; thickness, 4 in.; number, 12. 22. Patent; modification of Morgan's Patent. 23. About 22 tons. 24. 5 ft. 2 in. 26. Maudsley, Sons, and Field's Double Patent Cylinder. 27. 48½ diameter. 28. No. 29. Four. 30. Two copper cylindrical, each 44½ cubic feet. 31. Two, each 14 cubic feet. 32. Circular. 33. Not ascertained. 34. 25 revolutions. 35. Not ascertained. 37. 330·52. 38. 729·70 to 891·76; mean, 816·07. 39. 13½ to 15. 40. 25 to 25½. 41. Two. 42. Tubular. 43. See column 45. 44. Weight of boilers, 40 tons, 19 cwt., 1 qr., 20 lbs.; weight of water, 35 tons. 45. The boilers are now removed under which trials were made. The plans in the hands of the builders. 46. Twelve. 47. See column 45. 48. See column 45. 49. See column 45. 50. See column 45. 51. See column 45. 52. Tubular. 53. See column 45. 54. Two, 5 ft. diameter. 55. Fifteen. 56. 5580 lbs.

Return of Particulars respecting the Steam-ship 'Cambria' whilst under Trial.

1. Between Holyhead and Kingstown, six trips, 22nd to 26th of May, 1856. 2. S. to E.; windy and fine; tides favourable. Three trips. 3. 2 tons, 19 cwt., 1 lb. 4. 13 tons, 14 cwt., 1 lb. 5. Not ascertained. 6. 806·36 to 1174·80. 7. Paddle. 8. See column 1. 9. See column 1. 10. 14·07. 11. 19 ft. 9 in. 12. 201 sq. ft. 10 in. 13. 8 ft. 10½ in. 14. 840. 21. Diameter, 28 ft.; length, 7 ft.; breadth, 4 feet; thickness, 4 in.; number, 16. 22. Ditto. 23. About 23 tons, 10 cwt. 24. 5 ft. 10 in. 26. Side lever.

27. $73\frac{1}{2}$. 28. No. 29. Two. 30. Ordinary. 32. D. 33. Not ascertained. 34. 23 revolutions. 35. Not ascertained. 37. 392·10. 38. 806·36 to 1174·80; mean, 995·35. 39. $14\frac{1}{2}$ to $15\frac{1}{2}$. 40. $24\frac{1}{2}$ to 27. 41. Four. 42. Tubular. 43. See column 45. 44. Boilers, 66 tons; water, 60 tons. 45. The boilers are now removed under which trials were made. 46. Twelve. 52. Tubular. 54. Two, 5 ft. diameter. 55. Fifteen. 56. 5760 lbs.

Return of Particulars respecting the Steam-ship 'Scotia' whilst under Trial.

1. Between Holyhead and Kingstown, six trips, 17th to 21st of May, 1855. 2. S. to N.E.; light winds and fine; tides partly unfavourable. 3. 2·17. 4. 13·10. 5. Not ascertained. 6. 861·84 to 1007·16. 7. Paddle. 8. See column 1. 9. See column 1. 10. 15·68. 11. 192·7. 12. 188·78. 13. 8·10. 14. 680. 21. Diameter, 24 ft. 6 in.; length, 10 ft.; breadth, 3 ft. 8 in.; thickness, 3 in.; number, 12. 22. Patent; modification of Morgan's Patent. 23. About 23 tons. 24. 6 ft. 26. Maudsley, Sons, and Field's Double Patent Cylinder. 27. 52. 28. No. 29. Four. 30. Two copper cylindrical, each 51 cubic feet. 31. Two, each $16\frac{1}{2}$ cubic feet. 32. Circular. 33. Not ascertained. 34. 24 revolutions. 35. Not ascertained. 37. 379·92. 38. 861·814 to 1007·16; mean, 934·18. 39. 12 to $12\frac{1}{4}$. 40. $26\frac{1}{2}$ to 27. 41. Two. 42. Tubular. 44. Boilers, 47 tons, 3 cwt., 2 qrs.; water, 39 tons. 45. The boilers are now removed under which trials were made. 46. Twelve. 52. Tubular. 54. Two, 5 ft. diameter. 55. Fifteen. 56. 6240 lbs.

Return of Particulars respecting the Steam-ship 'Telegraph' whilst under Trial.

1. Between Holyhead and Kingstown, two trips, 29th of May, 1857. 2. S.W.; moderate and fine; tides partly favourable. 3. 2 tons, 18 cwt. 4. 15 tons, 8 cwt. 5. Not ascertained. 6. 1165·98. 7. Paddle. 8. See column 1. 9. See column 1. 10. 15·24 statute miles. 11. 243 ft. 8 in. 12. 224·70 sq. ft. 13. 9 ft. 8 in. 14. 1173. 21. Diameter, 26 ft. 10 in.; length, 10 ft.; breadth, 4 ft.; thickness, $3\frac{1}{2}$ in.; number, 14. 22. Patent; modification of Morgan's Patent. 24. 4 ft. 5 in. 26. Side lever. 27. $77\frac{1}{4}$ diameter. 28. No. 29. Two. 30. Ordinary. 32. D. 33. Not ascertained. 34. 25 revolutions. 35. Not ascertained. 37. 448·0. 38. 1165·98. 39. Fourteen. 40. Twenty-six. 41. Two. 42. Tubular. 44. Boilers, 70 tons; water, 65 tons. 45. The boilers are now removed under which trials were made. 46. Twelve. 47. Tube surface, 7382·76; furnace, 462·0; flame boxes, 747·0. 53. Number, 1128; length, 6 ft. 9 in.; diameter, $3\frac{3}{4}$ in. brass. 54. Two, 5 ft. diameter. 55. Fourteen. 56. 7800 lbs.

Return of Particulars respecting the Steam-ship 'Mersey' whilst under Trial.

1. Stokes Bay, 21st of April, 1859. 2. N.W. 4; smooth; ebb tide. 3. Not known. 4. Not known. 5. Not known. 6. 1088. 7. $30\frac{1}{4}$. 8. Mean, 2 runs, 13·459 knots. 9. Mean, 2 runs, 13·117 knots. 10. 13·288 knots. 11. Length, 254 ft. 5 in.; breadth, 30 ft. 12. 261. 13. 10 ft. 5 in. aft; 10 ft. 1 in. forward. 14. 1300. 21. Diameter, 21 ft. 4 in.; length, 8 ft. 6 in.; breadth, 3 ft. 5 in.; thickness, 3 in. 22. Feathering. 23. $13\frac{1}{2}$ tons. 24. 4 ft. 25. Not tried. 26. Oscillating. 27. 60 in. diameter; length of stroke, 5 ft. 28. Steam belt. 29. Two. 30. Ordinary. 31. Ordinary bucket pump. 32. India-rubber valves. 33. 81 tons. 34. $302\frac{1}{2}$ feet, $30\frac{1}{4}$ revolutions. 35. Unknown. 37. 250. 38. 1088. 39. 20 lbs. full. 40.

Per Maudsley's foreman, Condenser, 25½ in.; but 26 starboard and 26½ port engines, by our engineers. 41. Four. 42. Tubular. 43. 8 ft. 2 in. by 10 ft. 6 in.; 13 ft. 6 in. high. 44. 75 tons without, 120 with. 45. 1125 steam room, 1620 water room. 46. Eight. 47. 178 ft. grate surface, 4400 tube surface, 1007 other surface. 48. 528 cubic feet. 49. 1 ft. 2 in. at front, 2 ft. 6 in. at back. 50. 2 ft. 2 in. at front. 51. 30 square feet. 53. 864 brass tubes, 3 in. diameter, 6 ft. 6 in. long. 54. Two chimneys, 4 ft. diameter. 55. 20 lbs. 56. Not tried.—(Signed) H. V. Strutt, Examiner R.M.S.P. Co.

Return of Particulars respecting the Steam-ship 'Paramatta' whilst under Trial.

1. 7th of June, 1859. 2. Variable; moderate. 3. Unknown. 6. 2940. 7. Paddle wheels. 8. 14·008 knots. 9. 13·907. 10. 13·957. 11. Length, 329·5; breadth, 43·75. 12. 606·2 square feet. 14. 3862. 15. Centre of gravity of displacement, 3 ft. abaft middle of load line, and 8·41 ft. below. 21. Diameter, 38 ft. 6 in. over floats; ditto, 34 ft. 3½ in. at axis; floats, 12 ft. by 4 ft. 6 in. by 5 in.; fifteen floats on each wheel. 22. Feathering. 23. 69 tons. 24. 6 ft. 8 in. 25. Not tried. 26. Double cylinder. 27. Diameter, 68⅛ in. 28. No. 29. Four. 30. Ordinary. 31. Ordinary. 32. Conical valves. 33. 291 tons. 34. 17 revolutions per minute. 35. Not tried. 37. 764. 38. 2940. 39. 17½ lbs. gauge on boiler. 40. 26 in. vac. 41. Four. 42. Tubular. 43. Length, 24 ft. 9 in.; height, 21 ft. 11 in. 44. Boilers, 220 tons; water, 184. 45. Steam-room, 5292 cubic ft.; water-room, 6440. 46. Twenty-four. 47. Grate, 7 ft. by 3 ft. 6½ in.; by 24 in. tubes, 14696 square ft.; furnaces, &c., 2564 square ft. 48. 2636 ft. in four boilers. 49. 2 ft. 50. 2 ft. 6 in. 51. 127 square feet in the four boilers. 53. 2496 brass tubes; internal diameter, 3¼ in.; external diameter, 3½ in. 54. Two, 42 ft. long, 6 ft. 8 in. diameter. 55. 17 lbs. 56. Unknown.—H. V. Strutt, Examiner R.M.S.P. Co.

Return of Particulars respecting the Steam-ship 'Lima' whilst under Trial.

1. From Liverpool to Kingstown and back, May 20th, 1859. 2. Fresh breeze, northerly. 3. 3 tons. 4. 11 tons, 5 cwt. 5. 270,000 lbs. 6. 1160. 8. 13½. 9. 12¼. 10. 12. 11. Length on deck, 257 ft.; length between perpen. 251 ft.; breadth, 30 ft.; depth of hold, 17 ft.; depth to spar deck, 25 ft. 4 in. 12. 302. 13. Forward, 11 ft.; aft, 12 feet. 14. 1345. 21. Diameter, 26 ft. over all; do. 25 ft. 2 in. over floats; floats, 8 ft. 2 in. long, 3 ft. broad, ¾ in. thick. 22. Feathering. 23. 20 tons. 24. 4 ft. 26. Randolph and Elder's Patent Double Cylinder engines. 27. High-pressure cylinder, 52 in.; low-pressure do. 90 in. 28. Yes. 29. Four. 30. Common. 31. 17 ft. 32. Short slide, 24 in. by 6 in. 33. 200 tons. 34. 240 ft. 35. 100°. 37. 320. 38. 1150. 39. 24 lbs. 40. 28 lbs. 41. Two. 42. Tubular, superheated, 400° Fahr. 43. 12 ft. by 10 ft. 44. Boilers, 50 tons; with water, 68 tons. 45. 1000 cub. ft. 46. Six. 47. Grate, 136; steam, 1700; heating, including uptakes, 1500. 48. 480 ft. 49. 2 ft. 50. 2 ft. 6 in. 51. About 50 ft. 53. 258 iron tubes, 4 in. internal, 4¼ in. external. 54. One, 5 ft. diameter. 55. 27 cwt. 56. 25.

Return of Particulars respecting the Steam-ship 'Admiral' whilst under Trial.

1. Between the Cloch and Cumbrae Lighthouses, Frith of Clyde, distance 13·66 knots, 11th of June, 1858. 2. Tide, quarter ebb, favourable for, 13·66 knots; half ebb, adverse for, 13·66 knots. 4. 2206 lbs. per hour for 3¼

hours. 6. 744. 7. Paddles, 3303 in 2·305 hours. 8. 12·65 knots, or 14·55 miles. 9. 11·15 knots, or 12·82 miles. 10. 11·9 knots, or 13·69 miles. 11. 210 by 32. 12. 214 square ft. 13. 7 ft. 6 in., both. 14. 820 tons. 21. Diameter to Journals, 20 ft. 6 in.; 11 floats, 7 ft. long, 3 ft. broad and $\frac{3}{4}$ thick. 22. Feathering. 26. Double Cylinder. 27. Large, 4 ft. 3 in. stroke, $76\frac{1}{2}$ in. diameter; Small, 4 ft. 3 in. stroke, $48\frac{1}{2}$ in. diameter. 28. Steam-jacketed. 29. Four. 33. Engine and Boilers, 210 tons. 34. 24 revolutions. 38. 744. 39. Average, boiler 25 lbs., cylinder 19 lbs. 44. See column 33. 47. Grate, about 100. 56. 2206 lbs.—Certified by W. J. Macquorn Rankine.

Return of Particulars respecting the Steam-ship 'Emerald' whilst under Trial.

1. Ayr Bay, July 21, 1859. 2. Still water, light airs. 3. 30 cwt. 4. $13\frac{1}{2}$ cwt. 5. Not known. 7. 80 per minute. 8. 12 miles. 9. No tide. 10. 12 statute or $10\frac{5}{11}$ knots. 13. 10 ft. forward and same aft. 14. 150. 16. Diameter, 9 ft.; 3-blade; pitch, 14 ft.; area of blade, 20 ft. 17. 18 in. 18. 33 cwt. 19. Not known. 20. Not known. 26. Horizontal. 27. Length of stroke, 22 in.; diameter, 28 in. 28. No. 29. Two. 30. Common condenser, contents not known. 31. Trunk, 3476 cubic inches. 32. Common slide valve. Area not known. 33. Not known. 34. $293\frac{1}{3}$. 35. 95 degrees. 36. 56 ft. 37. Eighty. 38. Not known. 39. Not known. 40. Vacuum in condenser, $23\frac{1}{2}$ in. 41. One. 42. Tubular. 43. Depth, 11 ft.; length, $9\frac{1}{2}$ ft.; breadth, $13\frac{1}{2}$. 34. Not ascertained. 45. Not known. 46. Four. 47. 1313 ft. 48. 198 ft. 49. At door, 19 in.; at back, 26 in. 50. At front, 26 in.; at back, 19 in.; mean, $22\frac{1}{2}$. 51. $17\frac{1}{12}$. 52. Boiler tubular. 53. 270 iron tubes, $6\frac{1}{3}$ ft. long; exterior diameter, $3\frac{1}{8}$; interior, $2\frac{7}{8}$. 54. One, 26 ft. by 4 ft. diameter. 55. $13\frac{1}{2}$ lbs. 56. $13\frac{1}{2}$ cwt.

Continuation of TABLE 1, APPENDIX VII. For Mean Speed.

Nautical miles of Ship.	Difference.	Half Difference.	True Speed.
10·24			
7·32	2·92	1·46	8·78
10·8	3·48	1·74	9·06
7·84	2·96	1·48	9·32
10·39	2·55	1·27	9·11
8·71	1·68	0·84	9·55
9·54	0·83	0·41	9·12
7)64·84			6)54·94
9·26			9·156
20·8			
7·84	2·96	1·48	9·32
10·39	2·55	1·27	9·11
8·71	1·68	1·84	9·55
4)37·74			3)27·98
9·43			9·326

Appendix VII.—Table 1. Result of Experiments with the Yacht 'Undine,' July 6, 1858, on the measured mile at Greenhithe.

Immersion of Periphery, 1 ft. 8 in.
Displacement, 294 tons.
Diameter of Cylinder, 24 in.
Diameter of Screw, 7 ft. 10 in.
Draught of water, 8 ft. 6 in. forward, 11 ft. aft.
Length of Stroke, 15 in.
Pitch, 11 ft. 3 in. Length, 1 ft. 4 in.
Midsection, 154·33 square feet.

Number of Diagram.	Steam in Boiler per square inch.	Average through stroke per square inch.	Vacuum through stroke per square inch.	Total effective pressure per square inch.	Number of revolutions per minute.	Number of revolutions per trip.	Time of performing trip.	Horse-power exerted.	Rate in statute miles per hour.		Rate in nautical miles per hour.		Speed in feet per minute.		Per-centage of slip of Screw.	Remarks. Wind, Tide, &c.
									Ship.	Screw.	Ship.	Screw.	Ship.	Screw.		
No.	lbs.	lbs.	lbs.	lbs.			m s									
2a	13	9·8	10·23	20·03	95·89	561	5 51	131·64	11·8	12·26	10·24	10·64	1039·2	1078·78	3·68	With good ebb tide and calm.
2b	13	9·8	10·23	20·03												
3a	15	10·55	10·63	21·10	98·61	807	8 11	146·32	8·44	12·6	7·32	10·94	742·8	1109·4	33·14	Against tide, above 2 knots and No. 3 wind.
3b	15	11·56	10·59	22·12												
4a	17	13·16	10·33	23·49	104·5	580	5 33	172·04	12·45	13·36	10·8	11·26	1095·6	1175·4	6·79	With tide and wind astern.
4b	17	14	10·56	24·56												
5a	16·25	12·43	11·43	23·86	100·65	770	7 39	162·58	9·03	12·86	7·84	11·16	795·0	1132·2	29·79	Against tide, same wind as previous trial (hardly so strong).
5b	16 25	12·16	11·16	23·32												
6a	16·5	12·93	10·76	23·69	105·08	606	5 46	165·2	11·9	13·43	10·39	11·65	1054·2	1182	10·82	With tide, but nearly low water. Scarcely any wind.
6b	16·5	12·9	10·3	23·20												
7a	17	13·93	10·63	24·56	103·72	714	6 53	162·32	10·03	13·25	8·71	11·34	883·2	1166·4	24·28	Against tide. Nearly, if not low water. Wind ahead.
7b	17	13·06	10·86	23·92												
8a	15·75	11·6	10·6	22·2	103·72	650	6 16	159·58	10·99	13·25	9·54	11·34	967·2	1166·4	17·08	About low water. Wind slight astern.
8b	15·75	11·66	11·03	22·69												
Average of the whole	15·8	12·29	10·70	22·98	101·74	669·71	6 35	157·09	10·66	13·00	9·26	11·29	939·6	1144·575	18·0	
Average from 4a to 8b ...	16·41	12·88	10·75	23·54	103·53	664·00	6 25	164·32	11·02	13·34	9·45	11·35	959·0	1184·55	17·75	
Mem. of performance on trial, July 19, 1856.					Mean 108			Mean 162	9·92	13·5	8·6	11·69	872·96	11·88	26·25	Diameter, 6 ft. 6 in.; Pitch, 11 ft.; Length, 1 ft. 4. in.; Draught forward, 8 ft. 3 in.; Draught aft, 11 ft. 3 in.; Midsection, 148 sq. ft.

APPENDIX VII. (*continued*).—TABLE 2. Result of Experiments with the Yacht 'Undine,' July 29th and 30th, 1858.

Immersion of Periphery, 1 ft. 8 in. Diameter of Cylinder, 24 inches. Stroke, 15 inches.
3*a* Grade. Diameter of Screw, 7 ft. 10 in. Pitch, 11 ft. 3 in. Length, 1 ft. 4 in.
Cylinder filled nearly $\frac{2}{3}a$. Cut off $\frac{1}{3}a$. Draught of water forward, 8 ft. 6 in. Aft, 11 ft. 10 in. Midsection, 154·33 sq. ft.

Portion of Trip.	Number of Diagram.	Hour when diagram was taken.	Steam in boiler per square inch.	Average pressure through stroke per square inch.	Vacuum through stroke per square inch.	Total effective pressure per square inch.	Number of revolutions per minute.	Horse-power exerted.	Consumption of fuel. Per hour.	Consumption of fuel. Horse-power per hour.	Per-centage of slip of screw.	Rate in statute miles per hour. Ship.	Rate in statute miles per hour. Screw.	Rate in nautical miles per hour. Ship.	Rate in nautical miles per hour. Screw.	Speed in feet per minute. Ship.	Speed in feet per minute. Screw.	Remarks.
Holyhead to Calf of Man.	No.		lbs.	lbs.														
	1*a*	6·30 A.M.	16·0	13·86	11·53	25·39	94·0	154·13				55 miles in 5 hrs. 30 min., or 10·9 miles per hour.	12·01		10·4		1057·5	Wind slight ahead.
	1*b*			11·73	10·73	22·46												Tide against vessel.
	2*a*	7·30 "	14·5	11·66	11·07	21·86	101·0	150·39					12·91		12·0		1136·25	Set jib and foresail.
	2*b*			10·73	11·13	25·13												Wind shifted more easterly.
	3*a*	9·0 "	14·75	12·8	12·33	25·13	100·2	167·76			13·6		12·80	9·4	11·1	959·2	1127·5	More sail set.
	3*b*			12·2	11·53	23·73												Tide strong ebb with vessel.
	4*a*	10·30 "	16·0	12·6	11·63	24·23	99·3	160·84					12·69		11·08		1116·02	All sail set except mainsail.
	4*b*			12·0	10·6	22·6												
	5*a*	11·30 "	14·75	12·6	11·66	24·26	100·4	169·0					12·83		11·1		1129·5	
	5*b*			13·6	11·3	24·9												
Average ...		......	15·2	12·37	11·35	23·96	98·98	160·42			13·6	10·9	12·64	9·4	11·13	959·2	1109·35	
Calf of Man to Port Patrick.	6*a*	12·0 noon.	15·5	13·13	11·46	24·59	99·0	163·8				52 miles in 4 h. 30 min., or 11·55 miles.	12·67		11·08		1113·75	Tide strong with vessel.
	6*b*			11·1	11·4	22·5												Wind brisk.
	7*a*	1·0 P.M.	17·5	11·74	11·6	23·34	105·0	155·4			10·94		13·14	100·2	11·6	1012	1181·25	Wind falling off.
	7*b*			12·06	11·86	23·83												Took in sail.
	8*a*	3·30 "	15·0	12·46	10·8	23·26	99·0	161·12					12·67		11·08		1113·75	Sea smooth—wind slight.
	8*b*			10·9	11·56	22·46												
Average ...		......	16·0	11·89	11·44	23·33	101·0	160·10			10·94	11·55	12·82	100·2	11·25	1012	1136·25	
Port Patrick to the Mull of Cantyre.	9*a*	4·0 P.M.	16·0	12·16	11·67	23·83	102·0	166·9	3 tons of coal consumed in 12 hours, exclusive of raising steam.				13·04		11·3		1147·5	Jib and foresail set.
	9*b*			13·66	11·32	24·98												Sea calm.
	10*a*	4·30 "	14·5	10·9	10·03	20·93	97·0	150·6					12·40		10·7		1091·25	Wind slight.
	10*b*			12·0	11·46	23·46					3·18	12·1		10·5		1064·8		Sea calm.
	11*a*	5·0 "	14·75	13·07	11·11	24·18	98·0	164·4					12·5		10·8		1102·5	Wind slight in favour.
	11*b*			12·73	11·4	24·13												Jib and foresail set.
	12*a*	6·0 "	14·5	11·0	11·53	22·53	94·0	152·6					12·01		10·4		1057·5	Sea calm.
	12*b*			11·26	11·6	22·56												Wind slight.
Average ...		......	14·93	12·09	11·27	23·33	95·25	155·8	560·0	3·52	3·18	12·1	12·48	10·5	10·8	1064·8	1099·68	
Mean performance			15·37	12·11	11·35	23·54	98·40	158·77	560·0	3·52	9·24	11·5	12·64	9·97	11·06	1012·0	1115·09	

APPENDIX VII. (*continued*).—TABLE 3. Result of Experiments with the Yacht 'Undine,' October 26th, 27th, and 28th, 1858.

Immersion of Periphery, 1 ft. 8 in.
Bottom foul.

Diameter of Cylinder, 24 inches.
Diameter of Screw, 7 ft. 10 in.
Draught of water, 8 ft. 6 in. forward, 11 ft. 10 in. aft.

Length of Stroke, 15 in.
Pitch, 11 ft. 3 in. Length, 1 ft. 4 in.
Midsection, 154·33 square feet.

Portion of Trip.	Hour when diagram was taken.	Steam in boiler per square inch.	Average pressure through stroke per square inch.	Vacuum through stroke per square inch.	Total effective pressure per square inch.	Number of revolutions.	Horse-power exerted.	Per-centage of slip of screw.	Rate in statute miles per hour.		Rate in nautical miles per hour.		Speed in feet per minute.		Remarks.
									Ship.	Screw.	Ship.	Screw.	Ship.	Screw.	
	26th.	lbs.	lbs.	lbs.	lbs.										
Loch Ness …………	……	16·5	14·8	11·46	26·26	96·35	173·42	45·61	6·7	12·31	5·81	10·69	589·6	1083·93	Head wind strong all the
Loch Ness …………	……	16·5	14·96	11·56	26·52	96·35	175·14	45·61	6·7	12·31	5·81	10·69	589·6	1083·93	way to Fort Augustus.
Loch Ness …………	……	18·0	15·06	12·06	27·12	96·35	179·1	45·61	6·7	12·31	5·81	10·69	589·6	1083·93	22 miles by Chart.
		17 0	14·70	11·69	26·63	96·35	175·88	45·61	6·7	12·31	5·81	10·69	589·6	1083·93	
	27th.														
Loch Lochy ………	2 P.M.	17·0	11·1	12·13	23·23	99·07	157·68	30·29	8·83	12·66	7·66	10·99	777·04	1114·53	Fair. No sails.
Loch Lochy ………	……	17·0	11·2	12·16	23·36	99·07	161·46	30·29	8·83	12·66	7·66	10·99	777·04	1114·53	Wind slight.
Loch Lochy ………	……	17·5	11·13	11·51	22·64	99·07	153·6	30·29	8·83	12·66	7·66	10·99	777·04	1114·53	10 nautical miles by Chart.
		17·1	11·14	11·93	23·07	99·07	157·58	30·29	8·83	12·66	7·66	10·99	777·04	1114·53	
	28th.														
Sound of Jura ……	6 P.M.	15·5	8·76	11·6	20·36	99·065	138·2	– 2·02	12·92	12·66	11·22	10·99	1136·96	1114·25	Fair wind and with tide.
Sound of Jura ……	……	15·5	9·46	12·36	21·82	99·065	148·16	– 2·02	12·92	12·66	11·22	10·99	1136·96	1114·25	All available sail set until near the Mull, when
		15·5	9·11	11·98	21·9	99·065	143·18	– 2·02	12·92	12·66	11·22	10·99	1136·96	1114·25	wind fell off, and also more abeam; rough near
General average……	……	16·9	12·06	11·85	23·9	98·047	160·84	36·94	9·48	12·54	8·23	10·93	801·2	1104·23	the Mull. Cross tide. 100 nautical miles.
Average of Experiments, July 29th and 30th, Holyhead to Mull of Cantyre ………	……	15·37	12·11	11·35	23·54	98·40	158·77	9·24	11·5	12·64	9·97	11·06	1012	1115·09	

Appendix VII. (*continued.*) Table 4.—Experiments with Yacht 'Erminia,' October 12, 1858, in Stokes Bay.

Draft forward, 9 ft. 3 in. Immersion of periphery, 2 ft. 6 in. Diam. of cylinder, 15 in. Stroke, 18 in.
Draft aft, 12 ft. 11 in. Area of midsection, 149·18 sq. ft. Diam. of screw, 8 ft. Pitch, 13 ft.

No. of Diagram.	Steam in Boiler.	Average through Stroke.	No. of revolutions per mile.	No. of revolutions per minute.	Horse-power exerted.	Per-centage of slip of screw.	Rate in statute miles per hour.		Rate in nautical miles per hour.		Speed in feet per minute.		Remarks.
							Ship.	Screw.	Ship.	Screw.	Ship.	Screw.	
	lbs.	lbs.											
1	53	36·2	743	54·03	59·98	37·1	4·95	7·98	4·36	6·92	442·4	702·39	Against wind and tide.
2	53	32·7											
3	53	28·7	416	51·8	48·26	10·8	8·62	7·65	7·44	6·64	754·4	673·4	With wind and tide.
4	53	29·3											
5	50	34·16	615	53·4	58·68	23·86	5·91	7·88	5·21	6·84	528·6	694·2	Against wind and tide.
6	53	32·0											
7	50	32·77	440	50·28	51·44	6·2	7·87	7·42	6·85	6·44	695·1	653·64	With wind and tide.
8	50	30·94											

Report of the Proceedings of the Balloon Committee of the British Association appointed at the Meeting at Leeds.

The Committee met at Burlington House, London, on the 29th November 1858: present—

Colonel Sykes in the Chair, Lord Wrottesley, Dr. Lee, and Mr. Gassiot on the part of the Kew Committee.

Mr. Gassiot read the resolution of the General Committee appointing the Balloon Committee; namely—

"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 that purpose."

Mr. Gassiot, as Chairman of the Kew Committee, reported that, in consequence of the severe indisposition of General Sabine and of Mr. Welsh, he had not summoned the other members of the Kew Committee to attend this meeting.

Colonel Sykes read letters from Sir John Herschel and the Astronomer Royal, approving of further balloon ascents.

The question of expediency was discussed; and it was resolved, in consequence of the absence of three members of the Committee, and General Sabine and Mr. Welsh, to postpone the further consideration of the subject until the next meeting of the Committee, to be summoned by the Chairman.

Burlington House, 27th May, 1859.

Present, Colonel Sykes in the Chair, Lord Wrottesley, Professor Faraday, Professor Tyndall, and Dr. Lee.

Resolved,—That it is expedient for scientific objects that balloon ascents be renewed, due care being taken for the safety of the aëronaut, and the competency of the agents employed.

Resolved,—That Mr. Green be invited to meet the Committee at the next meeting.

Resolved,—That Admiral FitzRoy and Mr. Glaisher be added to the Committee.

Burlington House, 15 July, 1859.

Present, Colonel Sykes in the Chair, Lord Wrottesley, and Admiral FitzRoy.

Read a letter from Professor Tyndall, regreting his inability to attend the meeting, but offering his services to ascend in the balloon, and assist in the observations.

Mr. Green attended, and stated that himself and his balloon were at the disposal of the Committee whenever called for.

Colonel Sykes reported that the following gentlemen offered their services to ascend with the balloon as observers: Mr. E. B. Russell, and Mr. John Murray, students of medicine in Glasgow University, Mr. Storks Eaton of Dorsetshire.

Resolved,—That Colonel Sykes apply to the Chairman of the Kew Committee to have the instruments used in the former balloon ascents prepared for immediate use.

Resolved,—That Colonel Sykes be authorized to make the necessary arrangements with the several parties to be employed, preparatory to ascents which may take place either from Birmingham or Wolverhampton.

Consequent upon the above resolution, Colonel Sykes arranged the terms of compensation with Mr. Green for four balloon ascents—the first £30, the second £25, the third £20, and the fourth £15, the Committee paying for gas, and all incidental expenses. Lord Wrottesley was good enough to obtain a supply of gas from the Wolverhampton Gas Company, the use of their yard for the ascents, and the cordial assistance of their people. Monday, the 15th of August, was fixed for the ascent; and Mr. Storks Eaton, who had previously taken charge of, and made himself familiar with, the instruments, offered his gratuitous services to go up in the balloon. Lord Wrottesley, Admiral FitzRoy, Mr. Glaisher, and the Chairman assembled at Wolverhampton, at 1·30 P.M., to superintend the ascent. The weather was fine, but the wind came in gusts; the inflation, however, commenced; but the balloon filled slowly, and when 63,000 cubic feet of gas had been introduced, the evening was fast approaching; and as doubts were expressed of the ascent being made in safety, in consequence of the wind, the Committee resolved to defer the ascent until the following day.

On Tuesday, the 16th of August, the Committee assembled at 1·20 P.M.; the balloon had been completely inflated; but as the Committee were entering the Gas Company's yard, a gust of wind occasioned the neck of the balloon to flap so violently, that a rent of some yards was produced, and the gas escaped rapidly. This untoward accident stopped all further proceedings; and as Mr. Green said that the balloon could not be properly repaired within many days, as the balloon had received other injuries, the Committee were compelled to forego any attempt to effect balloon ascents before the approaching meeting of the British Association.

The Committee having thus reported their proceedings, recommend the reappointment of the Committee to carry out the objects which an accident has frustrated; and the Committee look to the concurrent opinions of the distinguished men who have expressed themselves favourable to further balloon ascents, having their due weight.

The Committee cannot close their report without expressing their oblig - tions to the Mayor of Wolverhampton, Mr. John Hartley, and to the Directors of the Gas Company, for their courtesy and cooperation. The thanks of the Committee are particularly due to Lord Wrottesley for his active and efficient aid, and for the reception of the Members under his hospitable roof at Wotesley Hall.

W. H. Sykes,
Chairman.

London, 20th August, 1859.

P.S.—Mr. Green not having fulfilled his engagement, was only paid his incidental expenses

	£	s.	d.
incidental expenses	£ 7	5	11
Gas	20	5	0
Expenses of Committee	12	0	2
Mr. Eaton's carriage of instruments and ether	1	13	6
Total	£41	4	7

Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution. By William K. Sullivan, *Professor of Chemistry to the Catholic University of Ireland, and the Museum of Irish Industry.*

Notwithstanding the evident importance of the phenomena of solution, not only in a purely physical and chemical point of view, but also in connexion with many of the most interesting geological and physiological phenomena, the subject, until recently, seems to have been almost altogether neglected, as if by common consent. Our knowledge respecting the solubility of any given substance in certain liquids, was usually comprised in such expressions as "soluble," "very soluble," "difficultly soluble," &c.—I might even say, is now comprised; for the law of solubility in water up to the temperature of 100° Cent. can scarcely be said to be known for a dozen salts, and has not been at all determined for higher temperatures or for other solvents. Since the admirable experiments of Gay-Lussac, by which he established the law of solubility of Glauber-salt, many important investigations, bearing upon the subject of solution, have no doubt been published; but, generally speaking, the immediate objects of these researches had to do with some other department of physics or chemistry, rather than with the establishment of a theory of solution. Among these I may mention Legrand's experiments on the influence of salts on the boiling-point, Frankenheim's on the capillarity of saline solutions, the well-known researches of Graham on the diffusion of solutions, of Person, Favre and Silbermann, Andrews, &c., on the latent solution heat of salts, Playfair and Joule's researches on atomic volume, and many others which it is needless to mention. Any experiments directly bearing on the subject which did happen to have been made with the view of determining numerical laws, were in general confined to the determination of the quantity of salt held in solution at different temperatures, and to the specific gravity of the solution. The range of temperature was usually limited to that between 0° and the boiling-point of the solvent, or to that of the dissolution. The uncultivated state of this important field of inquiry is no doubt to be attributed in part to the great labour required to work it, and the apparent insignificance of the results of even the most successful research. The recent laborious investigations of Löwel, Kremers, Gerlach, Wullner and others, show, however, that it is no longer likely to remain uncultivated; and from the enlarged views of the general physical relations of the phenomena of solution which these experimenters exhibit, we may expect most important results from their labours.

The graphic coordination of the results of experiments on the solubility of salts which have hitherto been recorded, lead to this capital fact, that within the limits of temperature embraced by the experiments, soluble salts may be classified into three groups :—1, those which, like sulphate of soda, attain a maximum of solubility within those limits, that is, give an ascending and descending curve; 2, those which, like common salt, have sensibly the same solubility at all temperatures within the limits; and 3, those which, like nitrate of potash and the majority of salts, increase considerably in solubility as the temperature rises. The fact of certain salts, such as sulphate and carbonate of soda, exhibiting a point of maximum solubility, or, as Löwel has shown, several such points, according to the modifications which take place in their molecular states, naturally suggests the probability that most salts would exhibit a point or points of maximum solubility, and a descending as well as an ascending curve of solubility, if we were to extend the range of our experiments to sufficiently high temperatures, provided they could resist without decomposition or volatilization such temperatures. And further, that many salts more or less soluble at common temperatures, may become wholly insoluble at high temperatures. In the case of sulphate of lime, the latter fact has been established by the observations of M. Couche and myself. From some preliminary experiments which I have since made, I think I shall be able to establish it in the case of many other salts likewise.

Although water under sufficient pressure retains its liquid form at temperatures far above 100°, the experiment of Cagniard de la Tour shows that if the temperature be raised sufficiently high cohesion will ultimately disappear, and the water will pass without alteration of volume into gas of enormous tension. Frankenheim and Brunner have both found that the elevation of water in capillary tubes decreases with the temperature, and that it is capable of being represented by a very simple formula of interpolation as a function of the temperature. If this formula were to hold approximately true at very high temperatures, it would enable us to trace the diminution of the cohesion as the temperature rises, until it would wholly vanish, which on this hypothesis would take place, according to Brunner, at 535°·38. Cagniard de la Tour made similar experiments upon some other liquids with like results. He found that the total gasification of ether took place at about 200°. The temperature at which the capillary height of ether would be zero, calculated by Brunner's formula, would be 191°·12. Wolf has experimentally found* that the capillary height was reduced to zero at 190° or 191°; above that temperature the capillary meniscus was below the level of the liquid, that is, there was capillary depression. At about 198° the strongly convex surface of the liquid appeared to cover itself with a thick cloud: at about 200° it was wholly changed into vapour. This striking coincidence between the calculated and experimental results, M. Wolf considers to be only accidental. Brunner's formula was founded upon experiments made within the limits of temperature of 0° to 35°, a range which M. Wolf thinks too limited. He has found, that, although the law of Brunner, that the decrease of the capillary height is proportional to the temperature, holds true up to 100°, it becomes more rapid above that point. Whatever may be the exact law for high temperatures, enough has been done to show that the decrease of capillarity may be employed as a measure of the diminution of cohesion at high temperatures. I think we may safely con-

* Ann. de Chim. et de Phys. vol. xlix. p. 230.

clude, both from Cagniard de la Tour's experiments and the theoretical results of Frankenheim and Brunner, that at a red heat water would be completely gasified. If instead of pure water we subject a saline solution to a high temperature, what would be the result? Long before the solution would attain the temperature at which water would pass into gas of the same volume, it seems probable that a large number of salts would become insoluble, owing to the gradual diminution of cohesion between the molecules of water. If this supposition be correct, the point of maximum solubility of a great many salts cannot be higher than 200° Cent. At very high temperatures water is capable of decomposing a large number of salts, even otherwise very stable double silicates; but as this action appears to depend in many instances upon the mass of the water, saturated solutions of salts heated under pressure, are not so liable to be decomposed as when salts are exposed to a current of hot steam. If the salt did not become insoluble before the water reached the point of gasification, and that it was capable of resisting that temperature without decomposition, and was not *per se* volatile at a red heat, we may conclude from the slight affinity between gases and solids, as well as from many other considerations, that the water and salt molecules would completely separate. The singular anomaly which boracic acid offers of being volatile in the vapour of water, a property which the experiments of Larocque* show belongs to many other fixed substances, also indicates that possibly several salts may not precipitate on the passage of the water into gas, but remain attached to the gaseous molecules. Under such conditions of temperature and pressure the most unforeseen phenomena may be presented to us.

The study of the laws of solubility of salts at very high temperatures is obviously, then, of very considerable importance. In undertaking their investigation I did not underrate the difficulty of the subject, though perhaps I did its extent. The most superficial consideration will at once convince any one that a mere table of the quantities of salt held in solution at different temperatures would be of very little value; and that, to be of any use, the investigation should include that of the action of salts in solution upon one another at those high temperatures. Further, as the study of the solubility of salts at any given temperature is but a particular case of the general question of solution, every such investigation must necessarily deal more or less with the whole of the phenomena of solution. The problem I proposed to investigate, while apparently limited enough, involves in fact the study of a very considerable branch of the physics of molecules. In so extensive a field of inquiry, and especially where we have to deal with very complicate phenomena, the study of which is beset with practical difficulties, and even danger, the individual investigator cannot hope to reap a very large return for his labour, however successful he may be. Every one who has worked at such subjects will understand that considerable progress must be made in an investigation of this kind before the results admit of being coordinated. Notwithstanding many unexpected interruptions, I have devoted a good deal of time in preliminary experiments upon the best methods of conducting my researches, and in endeavouring to devise apparatus for the purpose. Even though my progress were very rapid, instead of being very slow, as it has been, I should not be in a position to bring before you on this occasion a report of any numerical results which I may have obtained. It is due, however, to the Association to explain in a short preliminary report the point of view from which I am proceeding, and the extent and character of the field of research. As in so extended a subject any results obtained during the inquiry must be communicated piecemeal, such a preliminary report may

* Journ. de Pharm. vol. xiv. p. 345.

serve hereafter the very useful purpose of linking them together and indicating their relative importance until a final report can be drawn up.

In considering the subject which I propose to investigate, several questions immediately suggest themselves, which demand attention before entering upon the inquiry itself, as they relate to matters which constitute the groundwork of the whole subject. Of these I shall mention a few:—1. What is solution, and in what does it differ from fusion? 2. What special function does the solvent perform, and in what do water, alcohol, ether, and carbides of hydrogen differ in their solvent functions? 3. In what relation does water of crystallization stand to the other constituents of a hydrated salt? 4. When hydrated salts are dissolved in water, does the saline water still remain attached to the salt molecule, or does it mingle with the solvent? Or, in other words, in considering the physical properties of saline solutions, are we to regard them as made up of water molecules and anhydrous salt molecules, or as water and complex molecules of hydrated salts?

These questions have not been answered. No satisfactory hypothesis has even been proposed for the purpose. Neither can we hope to do so before the whole subject of molecular physics shall have considerably progressed beyond its present imperfect state. Still, although we cannot hope to answer those questions fully, they are so important in connexion with the special object of the present investigation, that they must necessarily be included as far as possible with it.

Many are inclined to consider solution as a case of chemical combination. In adopting this view, we do not, however, solve the problem; but if sufficient grounds existed for adopting it, we may consider doing so a step in advance, inasmuch as it would save us from the necessity of inventing a new form of force. If the test of chemical combination be, that the combining bodies unite in definite proportions, solution appears at first sight not to possess that characteristic. It appears to me, however, that we ought to distinguish two kinds of solution:—1, that of liquids in liquids; and 2, of solids in liquids. Some considerations founded upon the dynamical theory of heat may help us to understand this distinction.

According to that theory, the molecules of gases are so far separated as to be beyond the sphere of their mutual attractions, and they are further considered to travel onwards in straight lines according to the ordinary laws of motion. A gas may therefore freely flow into another, there being no cohesion between the molecules, and chemical attraction only when molecules which are strongly polar approach within the sphere of their attractive forces. In liquids, on the other hand, the repulsive action of motion is not sufficient to remove them beyond the sphere of their mutual attraction, notwithstanding that each molecule has not a determinate position of equilibrium, and may consequently freely change its place.

The liquid molecules are, in fact, assumed to be in a state of vibratory, rotatory, and progressive motion, so that each molecule is not permanently attached to another; but the progressive motion is not sufficient to carry it beyond the cohesive influence of the others. We may assume that great differences exist in the character and velocity of the vibratory and rotatory motions of the molecules of different fluids. The fluids, the molecules of which possess the same character of motion, may consequently mingle, because the molecules of each will not interfere with each other's motion. When the motions of the molecules of two fluids are incompatible, they do not mingle. The observations of Wilson and Swan upon the changes which one liquid produces in the form of the surface of contact of another, appear to support the view just stated.

Although fluids whose molecular motions are not incompatible may be able to mix in the same indefinite proportion as gases, true chemical combination may also take place between them. It is very easy to prove this in some cases, as, for example, when we add 27 parts of water to 63 parts of HO, NO_5; because in this case we have heat evolved, and the mixture has a fixed boiling-point, and may be distilled without decomposition. In other cases it is not possible to prove it. Change of volume, accompanied by the evolution of heat, can scarcely be considered a proof, inasmuch as we would assume as true the very thing we have to prove, namely, that the condensation is due to chemical combination. In the case of a mixture of alcohol and water, there is a considerable condensation, which may, as some suppose, be due to true chemical combination. M. Vergnette Lamotte, for instance, states that in congealed wine the alcohol and water are in definite proportions in the frozen part, an opinion not, however, adopted by M. Boussingault and others. This condensation may perhaps be accounted for in another way, which, however, it would take too much space to develope fully here, but which I shall have a more fitting opportunity of doing hereafter.

As the molecules of solids have a determinate position of equilibrium, their solution in any medium implies the exertion of a certain amount of force by the molecules of the liquid upon the solid. There is thus a distinction between the solution of solids and of liquids; the former partakes more of the character of chemical combination. It may be that when a solid is dissolved in water, it forms in the first instance a definite chemical compound which is liquid, and may therefore mingle with the uncombined water. If this hypothesis were correct, it would account for the absence of stoichiometrical relations between the quantity of salt and of the water in which it is dissolved, for a saline solution would be a compound of water and salt molecules mixed with n quantity of water. Some salts may possess the property of forming several such liquid compounds, others, perhaps, only one. There is considerable analogy between solution in the ordinary sense, and alloys, especially amalgams. Mercury appears to be capable of forming an endless number of compounds with several metals, some of which are solid and others liquid. The solid alloys freely dissolve in mercury. In the solution thus formed have we the original alloy simply dissolved in the mercury, or has a new compound been formed? If we cool the mixture crystals often separate, which may or may not be the alloy originally dissolved, according as the conditions under which they are formed are the same or different from those under which the alloy was first formed; exactly as when a salt separates from its aqueous solution at different temperatures with different proportions of hydrated water. The proportions in which mercury combines with metals are so numerous, and so unlike those which we meet with among the compounds of the metalloids, that we are perhaps justified in concluding that a metal dissolved in mercury is always in chemical combination, and that when the constituents of an amalgam or of other liquid alloys are not in definite proportion, we may account for it by supposing that it consists of some liquid alloy mingled with n quantity of mercury. As an example of the proportions in which mercury combines with the metals, I may mention the alloys made by Crookewitt*:—KHg_{20}; KHg_{25}; $Cd_2\,Hg_5$; $PbHg$; $BiHg$; $Ag_5\,Hg_{16}$; $AgHg_2$; $AgHg_3$; $AgHg_4$; $AuHg_4$.

Among the other arguments which may be urged in favour of solution being reckoned as a case of chemical combination, I may mention—1, that saline solutions in HO have a fixed boiling-point, a point of congelation, and, like water itself, a point of maximum density; and 2, that solutions are

* Ann. der Chem. und Pharm. vol. lxviii. p. 259.

homogeneous. Some experiments of Bischoff and Debus led to the conclusion that gravity acted upon a solution of a salt and caused an accumulation of the salt molecules in the lower portion of a column of the solution. Lieben has, however, found that the solution of a single salt is perfectly homogeneous. It yet remains to be proved whether saline solutions, containing a number of salts in solution, are homogeneous.

But if we admit the homogeneity of saline solutions, it appears to me that we must of necessity assume that in the solution the salt is combined with n molecules of water—n being variable according as the conditions of equilibrium are modified, or we shall be forced to admit the infinite divisibility of matter.

There is an evident relationship between solution and fusion. When a salt is fused, a quantity of heat is absorbed; when dissolved in water, a still larger quantity of heat is in most cases absorbed. Thus, according to Person*, 1 gramme of KO, NO_5 absorbs 49 heat-units of latent fusion heat; but if dissolved in 5 grms. of water, 69 heat-units are absorbed and 80 when it is dissolved in 20 grms. Whenever the same body is fused under the same pressure, the quantity of heat absorbed is always the same; but when a soluble substance is dissolved, the absorption of heat increases with the amount of water employed though not in a direct ratio. Even the dilution of a solution causes an absorption of heat; and with every successive dilution an additional quantity disappears, the only apparent limit being our means of detecting it. It is difficult to reconcile this phenomenon with that of homogeneity, unless we admit solution to be combination; and even then there must be a limit somewhere, unless we consider matter infinitely divisible.

The solution heat of a salt appears from the experiments of Person† to diminish as the temperature increases, a result which was pointed out by Graham, and which we might indeed have anticipated from the diminution of the specific heat according as the temperature rises, and from, as Person suggests, the specific heat of the saline solution being less than that of the separate constituents. On dissolving 1 grm. of chloride of sodium in 7·28 grms. of water at 70°, no absorption of heat was observed. Fusion, solution, and dilution are evidently but varieties of the same phenomena, and should be included together in any hypothesis framed to account for latent heat. MM. Favre and Silbermann proposed a very ingenious hypothesis to account for the latent heat of fusion: they considered it as the result of chemical combination or decomposition. They looked upon ice as isomeric water, n (HO), where n is any simple number; when HO becomes n (HO), heat is evolved; when, on the other hand, ice melts, that is n (HO) splits into HO, heat is absorbed. In the same way they looked upon a crystallized salt as an isomeric form of the same salt when in solution, *e. g.* SO_4 K, and $S_2O_8K_2$. This hypothesis would account for latent solution heat, which it would assimilate to latent fusion heat; by a slight modification it may be made also to account for the latent dilution heat,—by supposing crystallized salts to be higher multiples than that above assumed in the case of sulphate of potash, which may be considered to be n (SO_4 K); and that when it is dissolved in a small quantity of water, it splits into two or more molecules of a lower isomeric body, and this again into others on further dilution.

The modification here proposed seems to receive support from the discovery of a number of isomeric salts. For instance, Löwel‡ has obtained two salts with the empiric formula NaO, CO_2+7HO, of different solubilities,

* Compt. Rend. vol. xxxi. p. 566. † Ann. de Chim. et de Phys. (3) vol. xxxiii. p. 448.
‡ Ibid. vol. xxxiii. p. 334.

the one crystallizing in the form of rhombic, and the other in quadratic tables or flat prisms. He has likewise obtained* a salt isomeric with common Epsom salt, MgO, SO_3+7HO, and more soluble than it; it crystallizes in rhomboidal tables, which lose their transparency when taken out of their mother-liquor. Marignac has shown† that the quadratic crystals of sulphate of nickel have the formula NiO, SO_3+6HO, and that an isomeric salt crystallizing in the monoclinic system is formed at a temperature of from 50° to 70° Cent. Further researches will make us acquainted with many other examples of the same kind. The salts of manganese, cobalt, chrome alum, &c., present us with remarkable examples of molecular changes accompanied by striking changes of colour, in some of which we have true isomeric salts, as in the case of manganese, and in the case of chrome alum a difference in the amount of hydrated water. We should, however, distinguish clearly between the molecular changes which give rise to the isomeric salts, and those which are accompanied by a total alteration of physical properties. It is worthy of remark, too, that many chemists have been led, from wholly different reasons, to assume a more complex (as to the number of molecules) composition for salts and for chemical compounds generally. I may mention, for example, Avogadro's view, that the equivalent of a substance does not necessarily represent the relative weight of an integral molecule, but that the latter may be a multiple or an aliquot part of the former; and Hunt's‡, that all solid substances which have the same form, contain an equal number of atoms in equal volumes, a view which leads him to propose such a formula as $Na_{10}\,Cl_{10}$ for common salt. The existence of double salts of isomorphous bases containing a great number of equivalents of one combined with one or more of the other, and which are easily decomposed by merely dissolving them in a large quantity of water, is another circumstance which renders the hypothesis of Favre and Silbermann, and the application of it in a modified form above given, of increased interest.

If we adopt the hypothesis that crystallized salts are isomeric compounds, and that solutions are unstable compounds of salt molecules and water molecules, it seems to me that the phenomena of crystallization and solution, and perhaps the whole phenomenon of the change of physical state of bodies, may be referred to the category of double decomposition. It would lead me too far to attempt to develope this hypothesis here; indeed, without a good deal of experimental data to sustain my arguments, it would not be useful. I hope to be able to develope it fully on another occasion. I have mentioned it now, merely because it is intimately connected with the remaining questions which I have set down above, and which, with the exception of the fourth, I do not propose to discuss on this occasion.

There would obviously be a wide distinction between a solution containing the molecules MgO, SO_3+7HO, and one containing only MgO, SO_3. When we dissolve Epsom salt in water, which of the two solutions have we? The answer to this question depends to a considerable extent upon what may be the result of inquiries concerning the nature of solution. If a solution be a chemical combination between salt molecules and n molecules of water, the compound being liquid, and furthermore, if the crystallized salt be an isomeric form of the salt in solution, we must conclude that the water of the hydrated salt, as such, does not exist in combination with the salt molecule in solution, but becomes attached to it at the moment of the formation of the crystalline salt by a process of double decomposition. In assuming,

* Ann. de Chim. et de Phys., vol. xliii. p. 405.
† Liebig and Kopp's Jahresbericht, 1855, p. 411.
‡ Silliman's American Journal (2), vol. xv. p. 116.

however, that the formation of the crystallized salt is the result of double decomposition, we admit the existence of a specific molecular arrangement of salt and water in the solution, which under the same conditions of temperature, &c. always yields the same salt. That such a molecular arrangement does in reality exist, is proved by the fact that the same salt crystalizes with different amounts of hydrated water according to the temperature, a good example of which is afforded by sulphate of manganese. The lower the temperature, the larger will be in general the quantity of hydrated water which attaches itself to the salt molecule. Even salts which usually crystallize anhydrous, such as common salt, frequently separate in a hydrated form from solutions at very low temperatures. A solution of common salt cooled to $-10°$ yields transparent oblique rhombic prisms of the monoclinic system containing 4 equivalents of water. The large flat six-sided tables which Ehrenberg and Frankenheim observed to form under the microscope at the temperature of $+15°$, were most probably crystals of another hydrate. The formation of the double sulphates of the magnesian series is another striking proof of the pre-existence in a saline solution of a special molecular arrangement. The equivalent of constitutional water in MgO, SO_3, HO, 6HO is substituted in the double salts by an equivalent of an alkaline sulphate; this substitution must take place by double decomposition, and so far supports the hypothesis that all crystallizations are due to that process. As the substitution takes place in solution, we must I think admit, either that the salt has this equivalent of constitutional water attached to it in solution, or that some combination does occur there, which by double decomposition would give a crystalline compound in which it would exist. The existence of special molecular modifications in the constitution of salts, is assumed by Löwel to be the cause of the difference of solubility which the same salt sometimes presents at the same temperature, and not the amount of water which it takes up in crystallizing. This must necessarily follow as a relation of cause and effect if we adopt his view, that a salt is always present in solution in its anhydrous state. Such a view, however, compels us to admit that the salt molecule itself undergoes as many molecular modifications as there are distinct hydrates, and this under the influence of very slight causes; on the other hand, it does not satisfactorily account for the formation of such isomeric salts as those alluded to above, or for the effect of heat upon solubility. Gay-Lussac's view, that the hydrated water of the crystallized salt remains attached to the salt molecule in solution, affords no more satisfactory explanation of the phenomena in question, while that which it gives of supersaturation—the inertia of the saline molecules—is wholly untenable. Löwel's view, if we could account for the necessary molecular changes, would explain the phenomenon of supersaturation satisfactorily. It assumes that, strictly speaking, there is no such thing, and that solutions considered to be supersaturated merely contain salts having a different molecular constitution, and a different solubility from that ordinarily present at that temperature. The hypothesis that solutions are unstable compounds of salt molecules and water molecules, and crystalline salts compounds formed by their double decomposition, affords a simple explanation of the molecular changes required for accounting for supersaturation; and it especially enables us to distinguish between the molecular modifications which give rise to isomeric hydrated salts, and those offered by the green and violet modifications of chrome alum—the former may be assumed to affect the arrangement of the molecules of water and salt in the unstable compounds in solution; the latter and more profound, the salt molecules themselves.

Equal solubility does not necessarily imply that two salts are held by the solvent with equal force. It may be therefore that some salts do actually retain an equivalent of their water of crystallization attached to them in solution. Thomson's experiments lead to the conclusion that the third molecule of water in terhydrated phosphoric acid is not held so firmly as the others. On the other hand, Gerhardt has shown that when three equivalents of the strong base soda are substituted for the three of water in terhydrated phosphoric acid, the salt formed, $3NaO, PO_5$, has the power of retaining an equivalent of HO at the temperature of 100° Cent., which can only be removed at a temperature approaching redness, while the salt $2NaO, HO\ PO_5+24HO$ loses the whole of its crystalline water at 100°. It is probable that the equivalent of water thus retained, performs the same function as the constitutional water of the magnesian sulphates, and may be replaced by a salt molecule. Such salts as $3LiO, PO_5+2LiO, HO, PO_5+2HO$ and $3PbO\ PbO_5+PO, NO_5+2HO$ &c., may perhaps be referred to this type.

If we possessed some method of measuring the force with which salts are held in solution, we should be able to discover the law of its variation in the same class of salts according as one base was substituted for another, and for the same salt according as the temperature varied. The force with which a salt may be held by the solvent does not seem to bear much relation to its solubility. Charcoal removes salts of equal solubility from solutions in different proportions. It may, however, be justly objected to this, that the result is not due to a difference between the forces with which the salt and water are held together, but rather to the greater power of adhesion which the charcoal possesses for certain salts. I have begun a series of comparative experiments on the relative amount of different salts which pure charcoal and spongy platinum retain when solutions of various degrees of concentration are passed through them, the results of which will, I hope, throw some light on this subject.

The adoption of the hypothesis that crystalline salts are the result of double decomposition, appears to involve another consequence of great importance in the present inquiry, namely, that double salts do not exist as such in solution. In the case of double salts formed by the substitution of constitutional water, it is by no means necessary, as I have shown above, that the constituent salts of the double salt should be considered as existing uncombined in the solution, but simply in a different state of molecular arrangement. Favre and Silbermann were of opinion, however, that they did not exist in combination, and were only formed at the moment of their crystallization. Graham, from his experiments on diffusion, has likewise suggested the possibility of the constituents of a double salt being dissolved together in water without being chemically combined. The latter considered that diffusion was capable of producing chemical decomposition; for instance, that of bisulphate of potash, alum, and sulphate of potash in lime-water. This opinion harmonizes with the hypothesis of Favre and Silbermann; and if understood in the modified form above suggested, namely, that the double salt, such as we know it in its crystallized state, does not exist in the solution, but that the constituent salts are nevertheless not free in every case, would be perfectly accordant with it. Many isomorphous salts combine together in almost every proportion, such for example as the chromates and sulphates. H. Rose has analysed a compound of nitrate of silver and nitrate of soda to which he assigns the formula $AgO, NO_5+10NaO, NO_5$. If we adopt the hypothesis that crystallized salts are compounds of several molecules of the simple salt, we may consider the salt in question as $n\ (NaO, NO_5)$, in which one or more molecules of nitrate of silver replace a corresponding number of nitrate of soda. In accordance with that hypothesis, such a salt could not exist in solution, and we find that many of them are undoubtedly decomposed when dissolved in water. The simple double salts formed by non-isomorphous salts, such as those formed by the magnesian sulphates, the alums, &c., are compounds of a higher degree, and are held together with much more force, and in most cases are not decomposed by water at common temperatures. If the constituent salts of alum existed free in solution, it would be difficult to account for certain phenomena to which Chevreul first drew attention. If cotton be immersed in a solution of alum of a given strength, it will absorb some of it, but it will be found that the solution absorbed does not contain as much alum as the original one, that is, the cloth absorbs the water molecules more readily than the saline ones. Unless porous bodies, such as vegetable fibre, exert exactly the same adhesive power for sulphate of potash as they do for sulphate of alumina, which does not seem probable, the mere passage of a solution of alum through cotton, supposing the two sulphates not to exist in a state of combination in solution, would be sufficient to alter their relative proportions. The mere fact of vegetable fibre exerting unequal attraction for the constituent salts of double salts in solution, which in some cases at least it appears to do, would not, however, of itself constitute a proof that double salts did not exist, as such, in solution. It is very probable that the force binding the constituent salts of a double salt, and which is different for each one, is greatly diminished when the salt is dissolved in water; and that under those circumstances, the superior attraction of vegetable fibre, or porous bodies for one constituent salt, may be sufficient to overcome the chemical force by which the double salt is formed. The full investigation of this very important problem forms part of the series of experiments to be made on the action of charcoal, spongy platinum, and other porous bodies on saline solutions, already alluded to.

The preceding discussion on the condition of double salts in solution, clearly shows that we could not determine their solubility without taking into consideration the whole subject of the constitution of salts, the action of salts in solution upon one another, and the nature of solution. It fully justifies me therefore in viewing the subject which I proposed to investigate from the general point of view which I have done, instead of confining myself to the construction of a few imperfect tables, and which, though they may, if carefully constructed, be practically useful, could give very little aid towards the advancement of chemical theory.

If I have succeeded in the preceding pages in sketching so much of the general outlines of the subject of investigation as to convey an adequate idea of its character and scope, the classification which I have made of the several groups into which the experiments to be made may be divided for greater convenience of study, and the general character of the experimental processes which I have employed, or propose to employ, will be at once understood. A very brief account then of these two matters will complete what I proposed to do in this preliminary report: and first of the classification.

In an investigation involving so great a variety of detail, and in which so many physical phenomena must necessarily be employed as tests of molecular changes, the experiments require to be so classified that the results obtained in connexion with each class of phenomena shall be comparable, and that the results of one series of experiments shall throw light upon, and assist in carrying out the next, and lastly, that all shall converge to the main problem. The following scheme of experiments, if made upon an extensive scale sufficient to enable us to eliminate errors and anomalies, would afford us data to lay the foundation of a rational theory. The scheme embraces so much that I am in no danger of being suspected of the design of executing it all. It may be asked, why then sketch a plan which I could not execute? Because, in the first place, as I have already endeavoured to show, the determination of the true law of solubility of even a single salt, involves the whole of the questions which this scheme of experiments is proposed to investigate; and consequently, in any attempt to determine such a law, the whole of them must of necessity be more or less studied. And in the second place, because I believe that in the investigation of details we are apt to forget the generalities to which they are subordinate, an error which is avoided by following a plan in which every result, however trivial, finds its place and immediate use. Science will gain more in this way than by desultory experiments, which, in consequence of their isolation, remain for a long time barren.

1. I have found that many hydrated silicates, sulphate of lime, &c., when immersed in water and exposed to a high temperature, lost part or all their hydrated water. This suggests an important question—Do all hydrated salts lose their water, if heated in that liquid to a very high temperature? And if so, do any of them offer a similar phenomenon to that which certain hydrated salts present when heated in the air, namely, of losing their water in successive portions as the temperature rises? Thus, for example, the salt $2KO, PO_5+3HO$ loses one equivalent of HO at 100°, a second at 180°, and the third only perfectly at a red heat. The question suggested here applies to all salts that contain constitutional water. In such a salt as that above mentioned, is each molecule held by a different amount of force? and does it therefore enter with a different atomic volume into the compound? or is each equivalent held with the same force at the commencement of the operation, the change of constitution being the result of a modification of equilibrium produced by the heat? It appears to me that the study of the action of saturated solutions of salts upon the crystals of the hydrated salt at different temperatures would throw much light upon these questions, as well as upon the very important one of whether hydrated salts retain their water in solution. I hope very shortly to be in a position to report upon this branch of the subject.

2. The second series of experiments is to be devoted to the investigation of the influence which different proportions of an acid exert at different temperatures upon the maximum solubility of the different salts which it forms with such bases as do not yield any known higher acid salts than those experimented upon. Some singular anomalies are presented by salts in this respect, as, for example, the well-known ones, KO, NO_5 being more soluble in dilute nitric acid than in pure water, while BaO, NO_5 is precipitated from a strong solution by nitric acid. A similar series must be made for the influence of bases upon the solubility of such salts as they form, with those acids with which they do not yield recognizable basic salts.

3. The next series will be devoted to the study of the influence which different proportions of soluble acids exert, at different temperatures, upon the maximum solubility of soluble salts containing a different acid soluble in water, and with the base of which the intervening acid does not form an insoluble compound. In the cases contemplated here, there would be, according to Berthollet, decomposition in proportion to the mass of the intervening acid. We have direct evidence of this when HCl acts upon a solution of CuO, NO_5; but hitherto we have had no means of proving it where the solutions were colourless. Besides the obvious importance of such experiments in connexion with the subject of affinity generally, I think they will afford

the means of throwing some light upon the question, whether such a thing as single elective affinity does take place, or whether all combinations and decompositions are not cases of double decomposition? If the action of HCl upon CuO, NO_5, or of NO_5 HO upon CuCl, be a case of double decomposition, water must take part in it, and, like all other bodies, must act in proportion to its mass. The proportion of water must consequently be taken into account, as well as those of salt and acid; and if any means can be devised for ascertaining the amount of decomposition, experiments should be made with solutions of different strengths as well as with the saturated solutions.

4. The fourth series may be considered as a continuation of the last, and will consist of experiments upon the influence which different proportions of the soluble bases, KO, NaO, BaO, SrO, CaO, and NH_4O, exert at different temperatures upon the solubility of one another's salts. Here too we may assume double decomposition; in fact, all these bodies are present in solution apparently as hydrated oxides. Ammonia exerts a singular influence upon the solubility of some salts, such as sulphate of potash, which it precipitates from a strong solution. It would be interesting to include in the inquiry the action of the compound ammonias, as they will no doubt be found, while resembling ammonia in many respects, as regards their chemical function, to differ in respect to their influence on solubility. The action of the compound ammonias is interesting from another point of view likewise. Urea, as is well known, if added to a solution of common salt, causes it to crystallize in octahedrons. If we look upon urea as a diamide in which part of the hydrogen is substituted by a polyatomic radical, all other substances belonging to the same type may perhaps produce a like change. Difference of form in the same substance is generally, perhaps always, accompanied by a change of solubility; such a difference may perhaps exist between the two forms of common salt; so that this series of experiments is of considerable importance. The crystallization of common salt from urine in the form of octahedrons appears to have been known to Romé de Lisle. Fourcroy and Vauquelin showed* that this change of form was due to urea. Beyond this very important fact, little, if anything, was known of the influence of foreign substances upon the crystalline form of bodies, until the publication of Leblanc's memoir in 1788†. He made many valuable and interesting observations. But it is to Beudant‡, who brought together everything that was previously known on the subject, confirmed and very greatly extended the observations, that the subject is indebted for the interest and importance which it now has, and which has led to many new investigations. Among those who have more recently studied the subject, may be mentioned Nicklès, Senarmont, and Pasteur. The latter gives a very remarkable instance of this kind of influence§. The acid malate of ammonia crystallizes in rectangular tables of the rhombic system, sometimes having two parallel edges bevelled; the faces $\frac{P}{2}$ are never observed whenever the salt is crystallized from a pure solution. But if a part be heated until it has begun to be decomposed, and then dissolved in water, and the impure solution allowed to cool, the crystals formed in it have hemihedral faces, which disappear when the crystals are again made to grow in a pure solution. The action of nitric acid upon the nitrates of potash and of baryta, and of ammonia upon a solution of sulphate of potash, may be due to a change of this kind. The subject has never been

* Ann. de Chim. et de Phys. vol. xxxii. p. 80 (1799). † Journal de Physique, xxxiii.
‡ Ann. des Mines, iii. (1819), and Traité de Minéralogie.
§ Ann. de Chim. et de Phys. 3me Série, vol. xlix. p. 5.

systematically studied. The scheme of experiments proposed in the next section upon the influence which salts exert upon one another's solubility in virtue of their comparative morphology, may, however, afford an opportunity of doing something in this direction.

5. The fifth series of experiments will be devoted to the influence which salts exert upon each other's solubility. Strictly speaking, we may consider acids and bases as salts; but it will be better for the special purposes of this investigation to consider them separately. In studying the influence which substances exert upon one another in solution, we must take into account, not merely their chemical composition, but their crystalline form likewise. Even though we may admit that a hydrated salt, when dissolved in water, parts with its hydrated water, and that therefore the body which is in solution belongs to a different crystallographic system from the hydrated salt, there can be no doubt that some peculiar molecular condition must exist in the solution just before the separation of the hydrated salt, under the influence of which the molecules of anhydrous salt combine with a definite amount of water. We must also bear in mind, that in a great many instances certain molecular properties intimately connected with crystalline form, such as the power of circularly polarizing light, &c., are inherent in the molecules, and therefore independent of their physical state. I have thought it desirable, therefore, to classify the salts which I propose to experiment upon in this series according to the following crystallographic scheme:—

A. *Isomeromorphous bodies*, that is salts which crystallize in forms of the regular system, and possess similar formulæ. They may be subdivided into,— *a, isatomes*, or those which have equal atomic volumes, made up of the same number of integrant molecules; and *b*, *polyatomes*, or those which possess equal atomic volumes, but made up of an unequal number of integrant molecules—isomorphism being supposed to be in general due to equal or approximate specific volume.

B. *Icono-ideomorphous substances*, a name which Laurent first employed to designate such substances as the lævo- and dextro-tartaric acids, which are the images of one another viewed in a mirror, as Pasteur by his admirable researches has shown. Under this category will be included all hemihedral forms in opposite directions.

C. *Homœomorphous salts.*—True isomorphism can only exist between bodies crystallizing in the regular system, the term homœormorphism has accordingly been proposed to designate the isomorphism of the other systems, in which there is not perfect equality of angles or parameters. Laurent believed that two bodies ought to be considered as isomorphous, even though belonging to different systems, if their angles and parameters are nearly equal. He argued that if a rhombohedron of 103° can be considered to be isomorphous with one of 104°, 105°, or even of 107°, there is no valid reason why one of 89° 30′, or of 90° 30′ should not be isomorphous with a rhombohedron of 90°, that is with the cube which is the limiting form between the acute and obtuse rhombohedrons. It is in this sense I propose to use the term. I likewise propose to restrict the term to such bodies as have similar formulæ, and, like the isomeromorphous bodies, will divide them into *isatomes* and *polyatomes*.

D. Many substances can have exactly the same shape, or nearly the same shape, though they may wholly differ in chemical constitution. Such bodies cannot be considered as isomorphous or homœormorphous in the sense above contemplated. As identity of shape, however different the composition may be, must imply a certain amount of similarity in the conditions of equilibrium of their molecules, it is obviously of importance, in an investigation like the present, to examine the action which such bodies exert upon each other's solubility. This kind of isomorphism and homœormorphism may be described by the term *heteromeric*, first employed by Hermann. Heteromeric homœomorphism is in part what Laurent termed paramorphism.

E. Dimorphic and trimorphic substances may be isomorphic with two or three different series of bodies in as many different systems. This isomorphism may be *isomeric* or *heteromeric*. The influence which the bodies of each series would exert upon the solubility of a dimorphic salt would be extremely interesting, and especially as regards the comparative influence of the bodies isomorphic with the most stable form, and those isomorphic with the least stable at different temperatures.

F. The last category of forms includes the *hemimorphous* bodies in the sense in which Laurent used that term; that is substances which resemble each other in composition, but which are only partly similar in form—which have one or two angles alike, but all the others very different.

The application of this scheme of comparative morphology to the subject of this investigation is so obvious that I need not dwell upon it now. By submitting a salt in solution at different temperatures to the action of successive quantities of a number of salts, beginning with those which exhibit perfect identity of form, equality of volume, and similarity of composition, and proceeding downwards, as indicated in the preceding scheme, until remote indications of resemblance are alone perceptible, I hope to be able to ascertain the general character of the influence which form exerts upon solubility. To complete the series, it would perhaps be necessary also to study the action of salts which have no resemblance of any definite character.

The modification in solubility which a salt undergoes on adding a given quantity of another salt, is not, however, due to form alone; the chemical nature of the molecules engaged has perhaps a larger share in the phenomenon. The results of such a series of experiments as I have just planned would not therefore enable us to determine the influence of form, unless we could eliminate the effect due to chemical action, properly so called. This could only be done by making a series of experiments on the influence of chemical composition, according to a scheme of classification analogous to that sketched out for form. This will consist essentially of the following:—*a*, influence of a number of the soluble salts which the acid of the salt investigated forms with different bases; *b*, influence of the soluble salts formed by the base of the salt under investigation, with different acids; *c*, influence which the salts of sesquioxides exert upon the solubility of the salts of the protoxide of the same metal, and upon the protoxide of other metals, where they do not form recognized double salts; *d*, influence which salts of polybasic acids, with one, two, &c. of strong base exert upon the solubility of different salts; *e*, comparative influence of tribasic phosphate of soda, containing two of soda and one of water, and bibasic phosphate of soda with two of soda, &c.

I have perhaps discussed the classification which I propose to follow in my experiments sufficiently to make the character and scope of the investigation evident, and it now only remains for me to say a few words of the methods which I propose to employ in order to determine, if possible, the nature of the changes which take place on mixing saline solutions, and in heating a single solution, or a mixture, to a high temperature.

In the following observations upon the physical phenomena which may be taken advantage of to determine the molecular changes taking place without precipitation when solutions are mingled, I propose to mention those only which as yet I have tried with some hopes of usefulness. There are many others which I may hereafter try to make use of, and some of which have been employed for analogous purposes by others; such, for example, as the influence which solutions exert upon the spectrum, as shown by the ingenious experiments of Dr. Gladstone, who I hope may be induced to take up the whole question of the optical relations of saline solutions.

Relative Compressibility of Saline Solutions.—Among the most important physical phenomena the more complete study of which promises to throw light upon the nature of solution and the action of salts in solution upon each other, may be mentioned their compressibility. As all the experiments upon the solubility of salts at high temperatures must be conducted under high pressure, I must necessarily begin by investigating the action of pressure alone upon saline solutions in the cold. With the exception of the experiments of Grassi, made with Regnault's piezometer, we have no records of any in which saline solutions were examined. Grassi's, too, are mere isolated examples, not sufficient to enable a law to be established; the pressures, too, were very limited. The experiments of W. Thomson and Bunsen show that the point of solidification of bodies is lowered by pressure; hence we may expect that solutions of salts, if subject to pressure, would crystallize. There is a remarkable experiment of Perkins which bears out this supposition; he exposed glacial acetic acid with $\frac{1}{9}$th water to a pressure of 1100 atmospheres, and found that $\frac{7}{8}$ths of it had crystallized in a few minutes. In some trials which I have commenced, and in which I have used Epsom salts, nitrate of potash and common salt, high pressure alone appeared to produce crystallization. I obtained the pressure by the method employed by Degen* to ascertain whether oxygen and hydrogen combined with one another under great pressure. This method consists in decomposing water in a closed tube, by means of a voltaic current. I employed a U-tube, in one leg of which I placed the solution of the salt, and in the other the water to be decomposed. The decomposition was effected by means of two platinum wires soldered into the glass. Degen introduced a manometer-tube into his apparatus, by which he was able to register the pressure. In my first experiments I did not think this necessary, as they were only tentative. As it will be necessary to make a series of pressure experiments upon every salt the solubility of which I may seek to determine at high temperatures, in order that I may be able to determine what is due to pressure and what to temperature in the phenomena of solution at high temperatures, I must use a manometer in all future experiments. I am in hopes that a series of experiments made with Regnault's piezometer upon the comparative compressibility of concentrated solutions of single salts, and of mixtures of salts according to the schemes of classification, according to form and chemical composition above suggested, may give results which can serve to indicate molecular changes not otherwise recognizable. It is also probable that many new hydrates may be produced under the influence of great pressure; and that the character of the precipitates, the form, specific gravity, and other physical properties of salts crystallized under the joint influence of pressure, and the presence of other substances in solution, may present interesting modifications.

The experiments of Grassi having shown that the compressibility of distilled water free of air decreases as the temperature rises, while the compressibility of all the other fluids experimented upon increases with the temperature, the action of pressure upon the solutions of salts in water must be different from that which it exerts upon similar solutions in alcohol, ether, &c. I will not discuss this subject further here, as I hope very soon to be

* Poggendorff's Annalen, vol. xxxviii. p. 454.

able to bring forward the results of some experiments on this very interesting branch of the subject.

Capillary Ascension and Diffusion of Saline Solutions.—The experiments of Valson, Poiseuille, and Willibald Schmidt, indicate that the capillary height of fluids and the rapidity of their flow through capillary tubes is not altogether dependent upon their density, but is also influenced by the nature of the substances in solution. Valson * has examined the influence which the addition of one fluid would have upon the capillary height of another. He finds that this would be different according as the intervening fluid acted chemically or not upon the other; in the latter case only did the capillary height appear as a linear function of the increment of volume, while both those magnitudes may be expressed by an exponential curve with asymptotes when chemical action takes place. He has deduced the following results from experiments made with sulphuric acid (HO, SO_3), concentrated acetic acid, and alcohol, by the successive addition of increments of water to them:—1, that a change of capillary height takes place regularly as each successive increment of water is added; 2, the action of the successive increments upon the capillary height diminishes; 3, a modification of molecular activity exerts a greater influence on the capillary height than an alteration of specific gravity of the fluid mass; 4, the mixture of the bodies above named, although capable of being made in every proportion, may nevertheless be considered to belong to the category of chemical combination. Valson found that the addition of about $\frac{1}{10000}$ of alcohol to water produced an alteration of 0·2 millim. in a capillary column of 41·48 millims., which was very well determinable by the cathetometer.

The experiments of Poiseuille to which I refer, are those upon the flow of liquids through capillary tubes †. From those made with water and alcohol, he infers that the velocity of the flow is directly proportional to the pressure, and inversely to the length of the tube, provided that this length does not fall below a certain limit which increases and diminishes with the diameter; for shorter tubes he found that the velocity increases more rapidly than the pressure. He found further that, all other conditions being the same, the quantity discharged is proportional to the fourth power of the diameter of the tube. The addition of substances soluble in water modified, however, the velocity of flow; iodide, bromide, and cyanide of potassium, nitrate of potash, nitrate of ammonia, chlorides of ammonium and calcium, and acetate of ammonia accelerated it, while bases retarded it. Among the acids only two appear to have accelerated it,—hydrocyanic and hydrosulphuric acids. He only obtained negative results from his further researches to determine how far the alteration, produced by the addition of various substances, in the density, capillary height, liquidity, boiling-point, contraction on mixture, solubility and efflorescence of the substances added, &c., stood in any simple relation to the modification in the rate of flow. The experiments of Schmidt ‡ on the influence of temperature on the rapidity of filtration, confirm in the main Poiseuille's results just given.

I propose to use both the capillary height as determined by the cathetometer, and the flow of the solutions through capillary tubes, as tests of the molecular changes which take place in solutions of a single salt at different temperatures, and with mixtures of salts according to the schemes laid down above. The instrument which I am constructing for the experiments on the flow of the solutions consists of a modification of Vierordt's endosmometer, by which I can use tubular diaphragms of various lengths and diameters of tubes,

* Compt. Rend. vol. xlv. p. 101. † Ann. de Chim. et de Phys. vol. xxi. p. 76.
‡ Poggendorff's Annalen, vol. xcix. p. 353.

and apply a constant pressure during the whole time of the experiment. I propose, in addition to diaphragms composed of capillary glass tubes cemented together, to use also a series of platinum plates of various thicknesses, and pierced with holes of successively increasing diameters. By means of this instrument I shall be able not only to make experiments on the flow of liquids from a full vessel through capillary tubes into a space filled only with air, but likewise on the phenomenon of diffusion through such tubes—a kind of osmosis corresponding to what Fick calls pore diffusion.

Phenomena connected with Density.—The phenomena belonging to this category which may serve as tests of molecular changes in saline solutions, are,—1, density at various temperatures of solutions saturated at 0° and 100° and other intermediate points; 2, amount of condensation which takes place in saturated solutions when effected at different temperatures; 3, condensation which takes place on diluting saturated solutions with successive equivalent quantities of water; 4, density of supersaturated solutions at various temperatures; 5, point of maximum density of solutions; 6, influence of pressure upon the point of maximum density, and on the amount of condensation which results from dilution. The densities of a great number of saline solutions have recently been determined with great care by Kremers and Gerlach, and Löwel. These furnish valuable data both for scientific and practical purposes, and will be of the greatest assistance to me. In subjects of this kind, both on account of their extent and character, every observer has necessarily his own point of view, and makes use of different means to attain the same result. Thus for my special object I consider it better to confine my attention at first to saturated solutions, than to experiment upon solutions of different degrees of concentration. With regard to the point of maximum density, I shall only have to endeavour to continue what Despretz has so admirably begun.

Thermology of Saline Solutions.—I shall do little more than indicate on this occasion the phenomena connected with heat, which may be studied as tests of molecular changes. They are,—1, expansion of saturated saline solutions, already included under the head of density; 2, contraction of saturated solutions before they yield any crystals; 3, changes of volume which accompany crystallization; 4, point of congelation of saturated saline solutions; 5, boiling-point of saturated solutions; 6, latent solution and dilution heat of single salts, and of mixtures made according to the schemes laid down above; 7, specific heat of such solutions; 8, tension of vapours from saline solutions. Nothing need be said here on the subject of expansion of saline solutions, as the value of determinations of the rate of expansion can only be judged of as tests of molecular changes when we are in possession of data upon the other physical properties of solutions. The contraction which saline solutions undergo in cooling before crystals separate is of great importance, and in many cases will be found not to correspond to the expansion when heated through the same number of degrees. The changes of volume which accompany crystallization, and the point of congelation of saline solutions, are intimately connected with the subject of their latent solution and dilution heat and their specific heat. The study of these phenomena includes,—1, the determination of the specific heat of the solid and fused anhydrous salt itself, and of the hydrates which it forms; 2, similar determinations for mixtures of salts according to the schemes laid down above, whenever such mixtures can be fused together; 3, and lastly, of determinations of the latent fusion heat of simple salts and mixtures of salts. As regards the boiling-points of saline solutions, I propose to divide this part of the investigation into two parts; first, to determine the maximum effect which each salt experimented upon can produce in raising the boiling-point; secondly, to determine, as Legrand did for a great number of salts, how much of each salt would be required to raise the temperature of boiling by one degree Cent. successively from 100° to the maximum which the particular salt can raise it to; and thirdly, the effect of mixture in the laws established for the pure salt.

The study of the tension of vapours from saline solutions promises to be a very useful test of molecular changes. Regnault believes that the vapour from boiling saline solutions has the same temperature as the solution, and that the study of the tension of the vapours of such solutions might determine the important problem, whether salts were still joined to their crystalline water when in solution, and may in this way prove as useful a test as polarized light; and also whether double salts exist in solution, or are only formed at the moment of crystallization. Rudberg concluded from his experiments that the temperature of vapour arising from saline solutions was independent of the temperature of the solution. Von Babo has found* that the vapour from a boiling saline solution has less tension than steam of a corresponding temperature. Plücker has also found† that the vapour tension of saline solutions is less than that of pure water, and that the difference of tension may answer as a relative measure of the active molecular force between the salt and water, and of the law of its increase with the increasing quantity of salt. He states that the diminution of tension of the vapour is so directly proportional to the increase of salt, that the determination of this tension at 100° Cent. will give the per-centage of salt to solution, at least as well as the finest areometer. Wüllner‡ has also found that the differences of tension are directly as the quantities of salts dissolved. The differences of tension are represented by a differently expressed function of the temperature for each salt and mixture of salts. He also finds that no relationship can be established between the differences of tension and any of the other properties of the salts, especially the solubility; which fully bears out a conclusion which I came to above upon different grounds, that the force with which a salt may be held by the solvent, does not seem to bear much relation to its solubility. He also states that salts which cannot act chemically upon one another, modify each other's attraction for the water, when they occur together in solution. As it is doubtful whether any such salts exist, this would mean that all salts modify each other's affinity for water, when their solutions are mixed. Wüllner also considers the differences of tension to be a measure of the actual attractive force between the water and salt. It appears to me that the difference of tension can serve as a measure of the amount of decomposition which takes place on mixing two soluble salts which do not give a precipitate, and also of the influence of mass and of form in such decompositions at different temperatures. I accordingly propose to use them for that purpose, as well as also in conjunction with the experiments which I am making on the removal of salts from solutions by porous substances not acting chemically upon them, as a measure of the force by which salts are held in solution.

Plücker has also observed some very remarkable affinity relations which admit of being numerically determined when to a mixture of two fluids a third is added, or when a salt is dissolved in the mixture—which is indeed the case upon which he lays most stress, and the tension of the vapour determined, and from this the composition calculated. Thus, for example,

* Ann. der Chem. und Pharm. vol. lxvii. p. 356.
† Poggendorff's Annalen, vol. xcii. p. 193.
‡ Ibid. vol. ciii. 529; and vol. cv. p. 85.

water added to a mixture of alcohol and ether increased the tension of the mixed vapours and lowered the boiling-point of the mixture. In the same manner common salt considerably increases the tension of the vapour which rises into a closed space from a mixture of alcohol and water, and diminishes the boiling-point. Plücker did not experimentally determine the relative proportions of each vapour before and after the addition of the salt. It would not be easy to do so; but if it could be accurately done, it would be of great importance, for it seems to me to be necessary in order to control the calculated determinations, and help to give a correct explanation of the phenomenon. From some experiments made with mixtures of other substances, I have found that the relative proportion of each liquid which distils over from a mixture of two or more fluids, before and after the addition of a salt, is very different, but I have not yet determined the influence of temperature, relative proportions of the fluids forming the mixture, and of the mass of the salt, upon the proportions. The action of chloride of calcium upon a mixture of methylic alcohol, acetone, and a number of other liquids, the alcohol being in largest quantity, throws much light upon the phenomena observed by Plücker.

The mixture alluded to dissolves fused chloride of calcium with great facility; when a large quantity has been added, the fluid suddenly splits into two layers, the heavier of which contains the whole of the chloride of calcium, the lighter none. All the fluids of low boiling-points happened to separate from the chloride of calcium in the cases which I happened to observe. On heating the chloride of calcium solution in a retort, a large portion of the liquid distilled over; on adding water to the residue, and applying heat, another separation took place of some oily compounds, which distilled over along with water. If the mixture was distilled in the first instance before sufficient chloride of calcium had been added to cause the separation of the fluids, we should have an excellent example of the case described by Plücker. The molecular union of the atoms $\left.\begin{matrix}H\\H\end{matrix}\right\}O_2$ and $\left.\begin{matrix}C_4H_5\\H\end{matrix}\right\}O_2$ may be assumed to have been disturbed by the atom of NaCl, which had a stronger affinity for the water than the latter had for the alcohol; the alcohol was accordingly set free and lowered the boiling-point. The separation of the liquid into two parts does not always take place so evidently as in the case which I have above described, but it is probable the effect is essentially the same. If this explanation be true, certain salts ought to produce a diminution of tension, and the boiling-point ought to rise; thus, if we add a large quantity of salts which are more soluble in ether than in alcohol to a mixture of those fluids, the boiling-point ought to rise, unless the adhesion of the salt and ether be so much diminished by the heat, that the ether should separate again in part and distil over. I had an opportunity of observing an example of this kind in the case of some very volatile, oleaginous bodies, some of which combined with CaCl. Generally speaking, however, the heat required to vaporize the denser oils was sufficient to decompose the molecular combination with the CaCl, although it was sometimes possible to produce the splitting into two fluids. The whole subject is evidently one well worth further investigation, as I have no doubt that very great light would thereby be thrown upon the nature of solution. It also affords a measure of the comparative forces by which different salts are held by water and other solvents, and which I propose to make full use of for that purpose.

The diathermancy of solutions, which has been made the subject of investigation by Frantz, may likewise be made use of hereafter, as also the optical properties, such as their refractive and dispersive powers, &c. Kremers has already made many experiments upon the former. As I have not attempted anything in this direction as yet, I shall not dwell upon these subjects; the more so, as I believe I have fulfilled the object with which this preliminary report was written; namely, to give an idea of the character of the work I am engaged in, and the manner in which I propose to execute it. In conclusion, I shall only say a few words on one other feature of my plan of research which I hold to be of paramount importance. Hitherto I have only alluded to the subject of atomic volume, as a secondary element of morphological classification (*isatomes* and *polyatomes*). This has not arisen, however, from want of appreciation of the great benefits which chemical theory has derived from the introduction of the doctrine of atomic volume into science, and especially from the labours of Kopp and others in connexion therewith. The opinions put forward by Avogadro, Hunt, and others, whatever may be their intrinsic merit, show us that there exists as yet much room for diversity of opinion. On this account I will not, in the first instance, introduce the element of volume at all into the discussion of my numerical results. Many experimentalists have used in their experiments on points connected with molecular physics, quantities of the bodies operated upon which bear no relation to the proportional weights, according to which all chemical combination takes place. The remarkable laws of combination are too universally true to allow us to doubt that, although there maybe a difference between chemical and physical molecules, there must be some simple multiple relations between them. The remarkable relation established by Dulong between the proportional weights (equivalents) of bodies and their specific heat, is a striking confirmation of this opinion. In all the experiments which I propose to make, I will, as I have likewise heretofore done, always use the bodies operated upon in equivalent proportions. If we experiment on the physical properties of a single homogeneous substance, it makes no matter what quantities are employed, because by a simple calculation we can reduce our numerical results to equivalent quantities; it is quite otherwise, however, when we operate upon mixtures, for here any excess over the equivalent quantity influences the results, especially if we assume solution to be a chemical process. In this way I hope to be able to avoid all perplexing anomalies, arising from the presence of an excess of one constituent in a solution, which could interfere with the ready perception of any law governing the phenomena.

Provisional Report on the Progress in the Solution of certain Special Problems in Dynamics. By A. CAYLEY, *F.R.S.*

THE author stated the reasons which delayed the furnishing of the full Report, which he hoped to have ready for the next Meeting of the Association.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

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MATHEMATICS AND PHYSICS.

Mathematics.

Introductory Remarks by the President, The Earl of Rosse.

It has, I believe, been usual, at least recently, in opening the proceedings, to give, as far as may be practicable, a general outline of the business to be brought before the Section, and some kind of notice of the order in which it is likely to be taken. As, however, many papers are often sent in after the meeting of the Section, and as frequently circumstances arise rendering it necessary to alter the order of proceeding, any notice that can be given must be very imperfect; the daily notices, however, will in some degree supply the deficiency. It has also been usual, I believe, and it is obviously convenient, in some degree to define the general character of the business to be transacted, so that new Members may be enabled better to decide whether to attend this Section or some other. I have made inquiry, and find that already there have been received papers on pure mathematics, applied mathematics, magnetism, light, electricity, and meteorology, besides papers on the construction of philosophical instruments. From the titles of the papers, some idea may be formed of the general character of the business to be transacted; still there are many subjects, in fact several branches of science, which are as yet unrepresented in the papers.

First as to the papers on pure mathematics. I need perhaps hardly say that essays on so abstruse a subject cannot be of very much interest except to mathematicians; and even mathematicians, unless the papers happen to relate to the particular branches of mathematics with which they are most conversant, may perhaps be sometimes unable to do more than catch the general scope and leading principles of the paper; still without mathematical knowledge many may often, in the results announced, and indeed in the remarks casually elicited, obtain interesting glimpses into the nature of mathematical processes, and some idea of the progress making in that direction.

In applied mathematics there is much more of general interest, and the results are often perfectly intelligible without a special education. I recollect at the Meeting of the British Association at Oxford, the general results of a very abstruse investigation in applied mathematics in physical astronomy, were so brought forward as to rivet the attention of the whole Section. It was an account given in general terms by M. Le Verrier of his researches for the identification of a comet.

The discoveries in electricity, magnetism, heat, and light cannot fail to be of great general interest. To the human mind nothing is so fascinating as progress. It is not that which we have long had we most value, but that which we have recently acquired: we especially prize new acquisitions, while we enjoy almost unconsciously gifts of far greater value we have long been in possession of. This is our nature; thus we are constituted; it certainly is not surprising therefore that we should have a peculiar relish for new discoveries. The interest of a discovery is not usually confined to the discoverer, unless he is very churlish, or even to those who are endeavouring to discover; but it often extends to the whole civilized world. The interest is, however, not lasting; for a time we are dazzled by the brilliancy of the discovery; gradually, however, the impression becomes fainter, and at last it is lost entirely in the splendour of some fresh discovery, which carries with it the charm of novelty. When we reflect upon this, we cannot but perceive how very different the state of the world would have been had mankind from the beginning been in possession of all the knowledge we now have, and there had been no progress ever since. We ask, why have all these wonders been placed before us—hidden, veiled—only to be brought to light by the vigorous use of our faculties? How wonderful from its origin has been the progress of geometrical science! Beginning perhaps 3000 years ago almost from nothing, one simple relation of magnitude suggesting another; the relations becoming gradually more complicated, more interesting, more important, till in our day it expands into a science which enables us to weigh the planets; more wonderful still, to calculate long beforehand the course they will take acted upon by forces continually varying in direction and magnitude. When we ask ourselves such questions as these considerations suggest, and thoughtfully work out the answers as far as possible in their full depth of detail, we become in some degree conscious of the immense moral benefits which the human race has derived, and is deriving, from the gradual progress of knowledge. The discoveries, however, in physical science are often immediately applicable to practice, giving man new powers, enabling him better to supply his many wants. We therefore, who are all, in some degree at least, utilitarians, on that account very naturally regard them with deep interest. I am sure the mere mention of the subject has already suggested to you many of the extraordinary discoveries of latter times; for instance, the production of force almost without limit by heat, and its application to locomotion by sea and land,—the transmission of thought, not slowly by letter, not to short distances by sound, but instantaneously to immense distances by electricity; and when we look around us and see how man has appropriated to his use the properties of light and heat, the powers of wind and water, the materials which have been placed before him in endless variety on the surface of the globe which he inhabits,—that he has effected all this by knowledge accumulated by what we call Science,—it is surely not surprising that we should look upon new discoveries with surpassing interest. The mere utilitarian, however, has been often reminded that discoveries the most important, the most fruitful in practical results, have frequently in the beginning been apparently the most barren, and therefore that the discoveries in abstract science are not without interest even for him. I confess, however, that the gradual development of scientific discovery,—in fact, in other words, the steady flow of knowledge into the world—which like a stream becoming broader and deeper as it proceeds points to its own source, to its own origin, which is the origin of man,—I confess that this arrangement appears to me to serve far nobler purposes than merely to minister to the corporeal wants of man, as they increase, or are supposed to increase, with the progress of civilization. What those purposes are, to some extent, I think we may clearly see, though to fathom the full depth of such an inquiry would be beyond our powers. Looking merely on the surface, we perceive that the continual springing up of new facts, new discoveries, in endless succession, the rewards of industry, must tend to make man industrious. It inspires him with hope, entices him to labour with his mind—the hardest of all labour; it quickens his faculties, it forces him to look behind and before, to the past and future, and it promotes in him a high moral training by the influence it exercises over his habits and thoughts. Many, no doubt, will feel anxious to see principles immediately applied to practice; in common language, to see principles made useful: they will be highly gratified in the Mechanical Section. Here they may, perhaps, occasionally see the same thing; but more frequently they will find that the results are but stepping-stones which prepare the way for further progress. These few remarks, which I have made principally for the convenience of new Members, will, I think, be sufficient to give some little idea of the kind of business to be transacted here, and I will not allude to the actual practical results which have immediately followed from the labours of this Section. They have been detailed, and recently, especially by my friend on my right hand, Dr. Robinson;

and I will only further add, that I feel much gratified to find so large an attendance of eminent men of science here, ready to correct oversights and supply deficiencies. They, I am well aware, are far more competent to preside here than I can be; but, with their assistance, the duty will be light; and as the Council, no doubt on good grounds, have made the present arrangement, I will, without hesitation or misgiving, at once proceed with the business.

On the Probability of Uniformity in Statistical Tables. By R. CAMPBELL.

The object of this paper is to find a test for ascertaining whether an observed degree of uniformity or the reverse in statistical returns is to be considered *remarkable.*

Suppose the population to consist of n persons, which we will suppose nearly constant. Let a be the number of years during which observations are taken, and suppose the whole number of phenomena of a certain class occurring to, or presented by, the individuals in the population to be ab. We will suppose the phenomena of a kind which are not likely to occur to the same person more than once in the same year. [Of this nature are most important facts, of which such Tables are formed.] Now suppose we know *nothing* of the laws by which these facts occur, except that above given, namely, that the total number in a years is ab. Let us see what kind of uniformity (starting from that fact alone) we should expect the Tables to present.

Let the people alive in a particular year be $A_1, A_2 \ldots A_n$. The probability then of the phenomenon being presented in that year by A_1 is $\frac{b}{n}$. The probability that it will be presented by A_1 and *not* by A_2 will be $\frac{b}{n}\left(1-\frac{ab-1}{an-1}\right)$. Hence we can find the probability of its being presented by A_1 *only*; the probability of its being presented by *one person only*; the probability of its being presented by *two persons only,* and so on. These expressions will be very complicated. That for the probability of the phenomenon being presented by b persons only will be

$$\frac{(n-1)(n-2)\ldots(n-b+1)}{2.3.4\ldots b}.b.\frac{ab-1}{an-1}.\frac{ab-2}{an-2}\ldots\frac{ab-b+1}{an-b+1}\left(1-\frac{ab-b}{an-b}\right)$$
$$\left(1-\frac{ab-b}{an-(b+1)}\right)\ldots\ldots\left(1-\frac{ab-b}{an-(n-1)}\right).$$

Now though these expressions are complicated, we get some very simple results. The above expression would be deducible from the expression for the probability of the phenomenon being presented by $b-1$ persons only, by multiplying by a factor which reduces itself to $1+\frac{b(a-2)+n+1}{(n-b)(a-b)b}$.

It would be deduced from the expression for the probability of $b+1$ persons presenting it by multiplying by a factor, which reduces to

$$1+\frac{(a-1)n-(a-1)b+1}{(n-b)(a-1)b}.$$

Now these are always greater than 1. This shows that the average number is the most probable one to occur in a particular year.

The ratios of the probabilities of b occurring, to that of $(b-1)$, $(b-2)$, &c. are b to $b-1$,

$$\frac{n-b+1}{b}.\frac{ab-b+1}{an-ab-n-b}; \quad \ldots\ldots \quad \text{(a)}$$

b to $b-2$,

$$\frac{(n-b+1)(n-b+2)}{b.(b-1)}.\frac{ab-b+1}{an-ab-n-b}.\frac{ab-b+2}{an-ab-n-b+1}; \quad \ldots \quad \text{(b)}$$

. . . .

and so on.

b to $b+1$,

$$\frac{b+1}{n-b} \cdot \frac{an-ab-\overline{n-b-1}}{ab-b}; \quad \ldots \ldots \ldots \ldots \quad (\alpha)$$

b to $b+2$,

$$\frac{(b+1)(b+2)}{(n-b)(n-b-1)} \cdot \frac{\{\overline{an-ab}-(n-b-1)\}\{\overline{an-ab}-(n-b-2)\}}{(ab-b)(ab-b-1)} \quad \ldots \quad (\beta)$$

These results are capable of remarkable interpretations, which will be best illustrated by a numerical example, which by the aid of logarithms may be worked out with great ease *.

On Calculating Lunars. *By* Colonel Shortrede.

Besides the trigonometrically rigorous methods of reducing lunars, there has been during the last ninety years a multitude of approximate methods more or less exact, and no lack of subsidiary Tables for facilitating the solution.

The method here proposed is short and simple, and requires no subsidiary Tables beyond those of refraction and parallax, and the common Tables of logarithms to five places; and the result is always correct to within a quarter of a second.

The corrections in altitude into the cosines of the adjacent angles give the principal corrections on the apparent distance. We cannot from the given altitudes and distance get the cosines directly, but we find them by means of the versines. The right-angled triangles formed by perpendiculars from the true places to the apparent distance being calculated as plane triangles, the greatest possible error on the moon's correction cannot exceed $0''\cdot4$.

The smaller segment of the true distance is found by means of the logs used in finding the principal corrections, using as a first approximation the reduced or curtate distance instead of the greater segment. The cotangent of the greater segment to three places requires to be found; for the cot of the smaller segment we may use the complement of its log sine.

The squares of the perpendiculars are found by taking the product of the sum and difference of the corrections in altitude and in distance.

Logs to five places are required for the principal correction of the moon; for the other parts of the work, logs to three places will ordinarily suffice.

For the error on $M\mu$ as above found.

$$\tan M\mu = \tan Mm \cdot \cos m,$$

$$M\mu + \frac{M\mu^3}{3} + \&c. = \cos M\left(Mm + \frac{Mm^3}{3} + \&c.\right),$$

$$M\mu - Mm\cos M = \frac{Mm^3}{3}\cos M - \frac{M\mu^3}{3}$$

$$= \frac{Mm^3}{3}\cos M - \frac{Mm^3}{3}\cos^3 M$$

$$= \frac{Mm^3}{3}\cos M \sin^2 M.$$

For secondary corrections.

$$\cos \quad . \cos p = \cos h = \cos(b+d) = \cos b \cos d - \sin b \sin d,$$

$$\sin b \sin d = \cos b(\cos d - \cos p) = \cos b \,.\, 2\sin\frac{p+d}{2} \,.\, \sin\frac{p-a}{2},$$

$$\sin d = \cot b\,(\text{vers}\, p - \text{vers}\, d) = 2\sin^2 \tfrac{1}{2}p \cot b - \cot b \text{ vers } d,$$

$$\theta'' = \frac{\sin 1''}{2} p^2 \cot b - \&c.$$

* The above paper is published at length in the Philosophical Magazine for November 1859, and in the Assurance Magazine for January 1860.

For segments of true distance.

$$\sin I = \frac{\sin Mm \cdot \sin M}{\sin Im} = \frac{\sin Ss \cdot \sin S}{\sin Is},$$

$$\sin Is = \frac{\sin Ss \cdot \sin S}{\sin Mm \sin M} \sin Im = \frac{\sin So \cdot \sin ZM}{\sin Mm \cdot \sin ZS} \sin Im$$

$$= \frac{Ss \cdot \cos A}{Mm \cdot \cos a} \sin (ms - Is).$$

On the Figure of an imperfectly Elastic Fluid. By Professor Hennessy, *F.R.S.*

It appears that the shape of a mass of such a fluid is dependent on its volume in such a way that any abstraction from or addition to that volume will in general be attended with a change of figure. This proposition, when applied to the case of a mass in rotation, shows that if the earth has gradually passed into its present state from one of complete fluidity, the figure of the inner surface of the consolidated crust must be more elliptical than the stratum of fluid out of which it was formed. The actual amount by which the ellipticity would be so increased would depend upon the law of density of the fluid, but the general result of an increase in the value of the ellipticity is completely independent of the law of density, and of any hypothesis as to the constitution of the interior fluid mass.

Note on the Calculus of Variations. By Professor Lindelöf, *of the University of Helsingfors.*

In the problems with which the calculus of variations is concerned, it becomes necessary to regard the form of certain unknown functions as variable and capable of passing from any given form to any other in a *continuous* manner. The only way of rigorously establishing this indispensable continuity appears to be that followed by the illustrious Euler, that is to say, by the introduction of an arbitrary and variable parameter. The function which ought to vary, or rather change its form, is then regarded as a particular value of a more general function, which, besides the principal variables, also involves an arbitrary parameter, and the variation of the function is nothing more than its differential taken with respect to this parameter.

The calculus of variations has thus become a simple application of the differential calculus to the case where the function to be differentiated is a definite integral. The first problem which presents itself is to find the variation of the given integral, in other words, to differentiate the integral with respect to a parameter which it may contain in any manner whatever. This first problem has gradually received its complete solution through the researches of Euler, Poisson, and Ostrogradsky. But the moment we attempt to pass to the applications of the calculus we encounter a second, and more difficult problem, which for a long time has resisted the efforts of the greatest mathematicians; it consists in preparing the variation so that all its parts may be examined, in other words, so that the equations relative to the limits of the integral may be found. This preparation necessitates a series of partial integrations. Now the limits of the variables which, after the integrations, must be substituted for the variables themselves are so mixed up with each other, and with the variables themselves, that it appears impossible to take them into account by means of the system of notation in general use.

This difficulty has at length been happily overcome by an expedient, at once ingenious and simple, due to M. Sarrus of Strasburg. In a memoir to which the Parisian Academy of Sciences awarded a prize, M. Sarrus has introduced a new symbol to indicate the substitutions to be made in any expression, and by means of this symbol he has been able, not only to find the variation of a multiple integral, but to examine the same completely. We may add that Cauchy, in a memoir on the calculus of variations which he was never able to finish, adopts the innovation introduced by M. Sarrus, after slightly modifying the symbol of substitution in order to render it more accordant with the symbols of integration with which it is involved in researches of this kind.

My sole object in recalling these well-known facts has been to indicate the starting-point of my own researches on the calculus of variations, a few of whose results I have now the honour to communicate.

Following the example of M. Sarrus, I apply the term *definite expression* to any function whatever in which fixed values have been substituted for all the independent variables. Such a definite expression is no longer a function of these variables; it depends solely upon the parameters, that is to say upon the indeterminate constants, which it happens to contain.

It is at once seen that every definite integral possesses this property, the variables themselves being therein replaced by certain limiting values. In order to indicate, in other expressions, that a certain variable must be replaced by a particular value, we shall employ the symbol $|$; so that

$$\Big|^{x=x_1} u, \text{ or simply } \Big|^{x_1} u$$

denotes the result obtained by substituting the value x_1, in place of the variable x, in the expression u. In conformity with the notation of the integral calculus, the same symbol will also serve to denote the difference between the results obtained by two different substitutions. Thus the notation

$$\Big|_{x=x_1}^{x=x_2} u, \text{ or simply } \Big|_{x_1}^{x_2} u$$

denotes that the variable must be successively replaced by x_1 and x_2 and the first result subtracted from the second; so that

$$\Big|_{x_1}^{x_2} u = \Big|^{x_3} u - \Big|^{x_1} u.$$

The definition of a definite expression may now be more precisely expressed thus: it is a function submitted to integrations or to substitutions with respect to each of its independent variables. Such an expression is invariable so long as the constants which it contains preserve the same fixed values. But if it should contain an indeterminate parameter whose value changes, the expression in question will become a function of that parameter, and under this point of view may be differentiated.

This being granted, the most general problem of the calculus of variations, the problem in which, in fact, the whole theory of this calculus is contained, consists in finding the derived-function of any definite expression with respect to a variable parameter. M. Sarrus, it is true, has rendered the determination of this derived function possible in every particular case, but neither he nor Cauchy has given a general rule of differentiation applicable to every definite expression. I believe I have established this rule, and in the following manner.

Let us suppose the function V, containing any number of independent variables

$$x, y, z, \ldots\ldots s, t,$$

to be subjected to integrations or substitutions with reference, successively, to each of the variables according to the inverse order of their enumeration; so that the first operation shall refer to t, the second to s, and so on up to the last, which shall have reference to x.

Further, let

$$x_1, y_1, z_1, \ldots\ldots s_1, t_1$$

be the inferior, and

$$x_2, y_2, z_2, \ldots\ldots s_2, t_2$$

the superior limits of these variables.

The limits t_1 and t_2 of the variable t *may* be functions of $x, y, z, \ldots\ldots s$, but they *must* be independent of t. Similarly, the limits of the variable s may be functions of all the variables $x, y, z \ldots$ which precede it, and so on up to the variable x whose limits are independent of all the variables.

The result of these operations will be a definite expression, which, for brevity, may be represented by $\Box\mathrm{V}$. It is required to find the derived function of $\Box\mathrm{V}$ with respect to a parameter α, which may at the same time be contained in V and in all the limits of the variables.

For brevity we employ the symbols

$$\left|^{x_1}\frac{dx}{d\alpha}\right., \quad \left|^{x_2}\frac{dx}{d\alpha}\right., \quad \left|^{y_1}\frac{dy}{d\alpha}\right., \quad \left|^{y_2}\frac{dy}{d\alpha}\right., \quad \left|^{y_1}\frac{dy}{dx}\right., \quad \left|^{y_2}\frac{dy}{dx}\right., \ldots\ldots$$

as defined by the equations

$$\left|^{x_1}\frac{dx}{d\alpha}\right. = \frac{dx_1}{d\alpha}, \qquad \left|^{x_2}\frac{dx}{d\alpha}\right. = \frac{dx_2}{d\alpha},$$

$$\left|^{y_1}\frac{dy}{d\alpha}\right. = \frac{dy_1}{d\alpha}, \qquad \left|^{y_2}\frac{dy}{d\alpha}\right. = \frac{dy_2}{d\alpha},$$

$$\left|^{y_1}\frac{dy}{dx}\right. = \frac{dy_1}{dx}, \qquad \left|^{y_2}\frac{dy}{dx}\right. = \frac{dy_2}{dx}, \text{ \&c.}$$

This will clearly give rise to no error, since the expressions

$$\frac{dx}{d\alpha}, \quad \frac{dx}{d\alpha}, \quad \frac{dy}{dx}, \ldots\ldots$$

have, in themselves, no meaning whatever.

This being admitted, the general rule at which I have arrived may be thus enunciated.

In order to differentiate any definite expression with respect to a variable parameter α, neglect, in the first place, all the symbols of substitution and take the derived function of the remaining integral, treating the variables to which the above substitutions refer, as if each were a function of all the preceding ones and of α; in each term of the result restore the symbols of substitution before withdrawn. From the symbolical form which is thus obtained the true expression of the required derived function may be immediately obtained.

In order to illustrate the application of this rule, let us seek the derived function, with respect to α, of the expression

$$\Box\mathrm{V} = \Big|_{x}^{x_2} \int_{y_1}^{y_2} \Big|_{z_1}^{z_2} \mathrm{V}dy.$$

Neglecting, in the first place, the symbols of substitution, we must differentiate the integral

$$\int_{y_1}^{y_2} \mathrm{V}dy;$$

its derived function with respect to α is, according to the formula of M. Sarrus,

$$\int_{y_1}^{y_2}\left(\frac{d\mathrm{V}}{d\alpha}\right)dy + \Big|^{y_2}\mathrm{V}\left(\frac{dy_2}{d\alpha}\right) - \Big|^{y_1}\mathrm{V}\left(\frac{dy_1}{d\alpha}\right).$$

Now since x and z are the variables to which the neglected symbols of substitution refer, we must, on differentiating, proceed as if each of the three variables α, x, z were a function of those which precede it; that is to say, we must consider

z as a function of α and x, and x as a function of α. For the total derived functions, therefore, we shall have the values

$$\left(\frac{dV}{d\alpha}\right)=\frac{dV}{d\alpha}+\frac{dV}{dx}\cdot\frac{dx}{d\alpha}+\frac{dV}{dz}\left(\frac{dz}{d\alpha}+\frac{dz}{dx}\cdot\frac{dx}{d\alpha}\right),$$

$$\left(\frac{dy_1}{d\alpha}\right)=\frac{dy_1}{d\alpha}+\frac{dy_1}{dx}\cdot\frac{dx}{d\alpha},$$

$$\left(\frac{dy_2}{d\alpha}\right)=\frac{dy_2}{d\alpha}+\frac{dy_2}{dx}\cdot\frac{dx}{d\alpha}.$$

By introducing these values into the preceding expression, and afterwards re-establishing the symbols of substitution before withdrawn, we arrive at the symbolical formula

$$\frac{d.\square V}{d\alpha}=\Big|_{x_1}^{x_2}\int_{y_1}^{y_2}\Big|_{z_1}^{z_2}\left\{\frac{dV}{d\alpha}+\frac{dV}{dx}\cdot\frac{dx}{d\alpha}+\frac{dV}{dz}\left(\frac{dz}{d\alpha}+\frac{dz}{dx}\frac{dx}{d\alpha}\right)\right\}dy$$

$$+\Big|_{x_1}^{x_2}\Big|^{y_2}\Big|_{z_1}^{z_2}V\left(\frac{dy_2}{d\alpha}+\frac{dy_2}{dx}\cdot\frac{dx}{d\alpha}\right)-\Big|_{x_1}^{x_2}\Big|^{y_1}\Big|_{z_1}^{z_2}V\left(\frac{dy_1}{d\alpha}-\frac{dy_1}{dx}\cdot\frac{dx}{d\alpha}\right).$$

In order to deduce the true expression for $\frac{d.\square V}{d\alpha}$, we must decompose, successively, the triple symbols of substitution into simple ones, and afterwards replace the symbolical derived functions $\frac{dx}{d\alpha}$, $\frac{dz}{d\alpha}$, $\frac{dz}{dx}$, by the real ones which they represent, and which are determined by a prefixed symbol of substitution.

This rule serves to effectuate with facility all the reductions which have to be applied to the variation of an integral; but to enter into further details at present would be to demand too much from the patience of this illustrious assembly.

I shall merely add a short remark relative to the application of the calculus of variations to the investigation of the maxima and minima of definite integrals.

In seeking the absolute maximum or minimum of any integral S, containing one or more unknown functions, it is merely necessary to introduce into these functions an arbitrary parameter α in order to reduce the problem to that of finding the maximum or minimum of a given function. In fact, by so doing, the integral S becomes a function of α, and its maximum or minimum is determined from the equation

$$\frac{dS}{d\alpha}=\delta S=0.$$

But if, at the same time, certain other integrals S_1, S_2, &c.... are required to preserve the constant values

$$S_1=c_1,\ S_2=c_2,\ \&c......$$

during the variation of the unknown functions, the method just indicated does not suffice. In this case, which notwithstanding its frequent occurrence has scarcely ever yet been treated in a sufficiently rigorous manner, the result may be arrived at by a very simple expedient. Into each of the unknown functions let a number of parameters α, β, γ ... equal to the number of integrals S, S_1, S_2 ... be introduced; these integrals, which thus become functions of the parameters, may then be represented by

$$S=\phi(\alpha,\beta,\gamma...),\quad S_1=\psi(\alpha,\beta,\gamma...),\quad S_2=\chi(\alpha,\beta,\gamma,...),\ \&c.......$$

and it now remains to find, amongst all the values of α, β, γ...... which render $S_1=c_1$, $S_2=c_2$......, those which correspond to a maximum or minimum of S. According to the known principles of the differential calculus, it will suffice, therefore, to find the absolute maximum or minimum of the sum

$$S+aS_1+bS_2+......,$$

where a, b...... are arbitrary constants to be afterwards determined by the conditions

$$S_1=c_1,\ S_2=c_2\ldots\ldots\ldots\ldots$$

This result is not new; it was in fact known to Euler, though he admitted that his own demonstration was not complete. I have never yet been able to find in other works a sufficiently rigorous demonstration of this method.

On the Dynamical Theory of Gases. By Prof. J. C. Maxwell.

The phenomena of the expansion of gases by heat, and their compression by pressure, have been explained by Joule, Claussens, Herapath, &c., by the theory of their particles being in a state of rapid motion, the velocity depending on the temperature. These particles must not only strike against the sides of the vessel, but against each other, and the calculation of their motions is therefore complicated. The author has established the following results:—1. The velocities of the particles are not uniform, but vary so that they deviate from the mean value by a law well known in the "method of least squares." 2. Two different sets of particles will distribute their velocities, so that their *vires vivæ* will be equal; and this leads to the chemical law, that the equivalents of gases are proportional to their specific gravities. 3. From Prof. Stokes's experiments on friction in air, it appears that the distance travelled by a particle between consecutive collisions is about $\frac{1}{447,000}$th of an inch, the mean velocity being about 1505 feet per second; and therefore each particle makes 8,077,200,000 collisions per second. 4. The laws of the diffusion of gases, as established by the Master of the Mint, are deduced from this theory, and the absolute rate of diffusion through an opening can be calculated. The author intends to apply his mathematical methods to the explanation on this hypothesis of the propagation of sound, and expects some light on the mysterious question of the absolute number of such particles in a given mass.

Supplement to Newton's *Method of resolving Equations. By the* Abbé Moigno.

This was a mathematical paper, showing a method of greatly shortening and facilitating the finding of the roots of equations of a high order by the method of limits.

Note on the Propagation of Waves. By G. Johnstone Stoney, *M.A., M.R.I.A.*

This communication aimed at introducing less imperfect geometrical conceptions into the study of wave propagation, than those commonly applied. Each element of the front of a wave has been usually taken as the origin of a spherical disturbance, and the subsequent position of the wave simply regarded as the envelope of all such shells. This mode of treatment has the disadvantage of so imperfectly representing the phenomena, that it leads to great embarrassments. Thus it leaves the direction in which waves are propagated enveloped in great mystery, and most of the methods which have been suggested by geometers for removing the obscurity have failed to be satisfactory. The difficulty at once vanishes if we fix our attention in the first instance on the element whose disturbance at a given moment we wish to determine, and consider, along with its previous condition, all the influences which reach it at that moment. A spherical shell described round this disturbed element as centre, will in general (if the medium be homogeneous, &c.) pass through points from which the influence had started simultaneously; and if the entire series of such shells be considered, as well as the time at which the influence from each must have been thrown off to reach the common centre at the same moment, it will be easily seen, that, roughly speaking, the parts of the medium behind the disturbed centre were to a considerable distance in the same or nearly the same phase when they contributed to its disturbance, whereas those parts in front of it were in rapidly succeeding phases. From this it follows that the influences arriving from behind will have a great preponderating resultant in one direction, while those arriving from the parts in front will almost cancel one another. This clears up at once the maintenance of the onward propagation of an undulation.

The points of the medium, which were in strictly the same phase as the disturbed element when they transmitted their influence, lie in general (on the hypothesis of homogeneity, &c.) on a surface of revolution round the wave-normal, and passing through the disturbed point. This surface of revolution (which, if we make the simplest hypotheses, becomes a right cone) is of importance in the theory of waves.

If the medium be such that the disturbing influence is but little enfeebled by distance, this cone will obviously be of small angle, and therefore nearly coincide with the backward part of the wave-normal. In such a medium waves will therefore spread but little laterally. A constitution of this kind probably contributes materially to the rectilinear propagation of light, and explains a phenomenon which shows that the common account does not universally hold, viz. the known fact that sound in water bends with less facility round obstacles than sound in air, although the waves constituting it are longer.

It is necessary to form a clear conception of what is to be understood by the influence contributed by an element of the medium. The parts beyond one of the spherical shells produce an effect on the central disturbance. This effect is modified by the particular condition in which that shell was at some time previous to the central disturbance. It is this modification which is to be regarded as the influence of that shell; and so of the rest. The resultant is therefore to be obtained by integrating from without inwards.

After the conditions which must be attended to when the influence is transmitted from each origin of disturbance with unequal speed in different directions, or is not at a given moment limited to a surface, &c., were referred to, some applications of the method to familiar phenomena which do not admit of easy explanation by the usual methods, were given.

On the Relations of a Circle inscribed in a Square. By J. Smith.

On the Angles of Dock-Gates and the Cells of Bees. By C. M. Willich.

The author showed by trisection of the cube along different planes, the production of various solids, and the relation of these to natural forms known in crystallography, to the bee's cell, and to the theoretical meeting angle of dock-gates (109° 28′ 16″). Thus a rhomboidal dodecahedron is composed of four rhombohedra. The bee's cell may be imitated by an elongated dodecahedron composed of seven rhombohedra.

Light, Heat, Electricity, Magnetism.

On a New Species of Double Refraction. *By* Sir David Brewster, *K.H., LL.D., F.R.S.*

In 1813 Sir David Brewster discovered that when a ray of light is transmitted obliquely through a bundle of glass plates it is completely polarized; but he at the same time noticed that this beam is accompanied with other rays, sometimes nebulous, and sometimes in separate distinct images (depending on the polish and parallelism of the glass), but polarized in an opposite plane*. This fact was overlooked by Arago and Herschel in their subsequent researches on the same subject, and was not further pursued by Sir David Brewster at the time.

In recently examining, however, several hundred films of decomposed glass of extreme thinness, on which the polish and parallelism of the surfaces enabled him to resume the study of the compound beam, he obtained the following results:—

1. When a beam of polarized light is incident obliquely upon a pile of thin and homogeneous uncrystallized films, and subsequently analysed, the transmitted light will exhibit the phenomena of negative uniaxal crystals, that is, it will consist of two

* See Phil. Trans. 1814, p. 225–230.

oppositely polarized pencils, which produce by interference all the colours exhibited by such crystals under similar circumstances.

2. The two oppositely polarized pencils are, first, the pencil polarized by refraction at each surface; and secondly, the pencil, or rather the fasciculus of pencils reflected from the surfaces of each film, and returned into the transmitted beam.

As these phenomena are exactly the same as those produced by double refraction, the author did not hesitate to call the result a new species of double refraction, or a new process in which the phenomena of double refraction are produced.

On the Decomposed Glass found at Nineveh and other places. By Sir David Brewster, *K.H., LL.D., F.R.S.*

The author described the general appearance of glass in an extreme state of decomposition, when the decomposed part was so rotten as to break easily between the fingers, a piece of undecomposed glass being generally found in the middle of the plate. He then explained how, in other specimens, the decomposition took place around one, two, or more points, forming hemispherical cups, which exhibit the black cross and the tints of polarized light produced by the interference of the reflected with the transmitted pencils. In illustration of this decomposition, he showed to the Meeting three specimens, in one of which there was no colour, but which consisted of innumerable circular cavities with the black cross, these cavities giving it the appearance of ground-glass. In another specimen the film was specular and of great beauty, showing the complementary colours by reflected and transmitted light. In a third variety the films were filled with circular cavities exhibiting the most beautiful colours, both in common and polarized light. Various other remarkable properties of these films were described by the author.

On the Submergence of Telegraph Cables. By H. Cox.

On the Stratified Electrical Discharge, as affected by a Moveable Glass Ball. By J. P. Gassiot, *F.R.S.*

If the discharges from an induction coil, when taken in a good carbonic acid vacuum tube, are examined with care, it will be seen that the stratifications nearer the negative terminal are remarkably clear and defined, oftentimes showing clearly separated cloud-like luminosities, but gradually becoming indistinct and intermingled with each other towards the positive terminal wire. This difference in the character of the stratified discharge becomes more perceptible to a certain extent as the vacuum improves; for when the stratifications are close and narrow, they are regularly diffused throughout the entire length of the luminous discharge.

In a tube 18 inches long and $1\frac{1}{4}$ inch wide, I inserted a small bead of uranium glass about $\frac{1}{4}$ of an inch in diameter. Transparent uranium glass, Professor Stokes has shown has the property of becoming opake by the electric light, and this is very beautifully shown in these tubes, but more particularly when the negative discharge is made to impinge on the bead. If during the discharges the tube is inclined so as to permit the bead to roll down, the discharges will give the appearance as if a distinct row of separated beads were present; this appearance arises from the number of discharges which take place during the rotation, each discharge separately and distinctly illuminating the bead.

The peculiar phenomenon which I, however, desire to bring before the notice of the Section is one which I only very recently noticed. I have already stated that the stratifications near the positive wire are indistinct; but if the glass bead is placed near the positive wire and then allowed slowly to descend towards the negative, the stratifications at the positive are at first as clearly defined near that terminal as at the negative, and as the bead rolls gently down, they have the *appearance* of following the bead and issuing one after the other from the positive wire, until the bead reaches to within a few inches of the negative, when this action gradually ceases. If the tube is now inclined so as to allow the glass bead to return in the contrary direction, the stratifications appear to recede, becoming more and more clearly defined, until the bead passes the positive terminal wire, when the entire discharge returns to its normal state.

On the Relation between Refractive Index and Volume among Liquids. *By the* Rev. T. P. Dale and J. H. Gladstone, *Ph.D., F.R.S.*

The authors referred to a previous paper, in which they had shown, among other things, that the *sensitiveness* of a substance is not directly proportional to the change of density produced by an alteration of temperature. The theoretical formulæ relating to the dispersion of light afford little assistance in determining what this relation is, but a series of careful observations had been made with a view of arriving at some empirical formula. It was found that the product of the volume, reckoned as 1000 at the boiling-point, and the refractive index for the line A of the prismatic spectrum less unity, gave numbers which were nearly constant. In the case of water, alcohol, pure wood-spirit, and bisulphide of carbon, however, the volume increases a little faster in proportion than the refractive index less unity diminishes, while with ether the reverse is the case. The regularity of the numbers shows that this is not due to errors of experim nt. The authors propose examining the subject more closely.

On the Theory of Light. *By* G. F. Harrington.

Notice of Experiments on the Heat developed by Friction in Air. *By* J. P. Joule, *LL.D., F.R.S.*

The research which Professor Thomson and myself have undertaken on the thermal effects of fluids in motion, naturally led us to examine the thermal phenomena experienced by a body in rapid motion through the air. The experiments which we first made for this purpose were of a very simple kind. We attached a string to the stem of a sensible thermometer, and whirled it alternately slowly and rapidly. In this way we uniformly obtained a slight effect; there was a higher temperature observed immediately after rapid, than after slow whirling. A thermo-electric junction rapidly whirled also gave us an appreciable thermal effect, indicated by the deflection of the needle of a galvanometer.

Afterwards a more accurate set of experiments was made by us; using a lathe, to the spindle of which an arm was attached carrying one of Professor Thomson's delicate ether or chloroform thermometers. The thermometers employed were so extremely sensitive that each division of their scales had a value of not more than $\frac{1}{300}$ of a degree Centigrade. The great value of Professor Thomson's thermometers in the whirling experiments, was further enhanced by the light specific gravity of ether comparatively with mercury: the pressure produced by centrifugal force operating on a long column of mercury, would have probably broken a mercurial thermometer whirled at high velocity.

The results arrived at by Professor Thomson and myself were as follow:—

1st. The rise of temperature in the whirled thermometer was, except at very slow velocities, proportional to the square of the velocity.

2nd. The velocity at which the bulb had to travel in order that its temperature should be raised 1° Cent. was 182 feet per second.

3rd. At very slow velocities the quantity of thermal effect appeared to be somewhat greater than that due from the square of the velocity calculated from the above datum; and we surmised that this was owing to a sort of fluid friction different from the source of resistance at high velocities. We therefore made several attempts to increase this fluid friction; the most successful result being obtained by wrapping fine wire over the bulbs. By this means we succeeded in obtaining the $\frac{1}{6}^{\circ}$ from a velocity of 30 feet per second, a quantity five or six times as great as that which took place when the naked bulb was revolved at the same velocity.

We resumed the whirling experiments last May; and it is owing to the circumstance that it has happened that I have myself been principally engaged in making those which I am about to communicate to the Section, that Professor Thomson has requested me to give an account of this part of our joint labours.

Our object was to repeat the former experiments under new circumstances, so as to verify and extend the results already obtained. A very brief outline can only be given in this place, as we intend shortly to incorporate them in a joint paper for the Royal Society, to whose assistance we owe the means of prosecuting the inquiry.

The lathe was again used as the whirling apparatus, but instead of the ether thermometer, we whirled thermo-electric junctions of iron and copper wires. We obtained the following results :—

1st. The law of the thermal effect was, as with the ether thermometer, proportional to the square of the velocity.

2nd. The rise of temperature was independent of the thickness of the wire which formed the thermo-electric junction which was whirled. This was decided by experiments on wires of various diameters, ranging from $\frac{1}{100}$ to $\frac{1}{8}$ of an inch diameter. The rise of temperature was in any of the wires the same as that obtained with the ether thermometer, the bulb of which was nearly half an inch in diameter.

3rd. The thermal effect appeared likewise to be independent of the shape of the whirled body ; little difference happening in whatever direction the wire was placed.

4th. The average result was that the wire was warmed 1° by moving at the velocity of 175 feet per second.

The highest velocity obtained was 372 feet per second, which gave a rise of 5°·3, and there was no reason to doubt that the thermal effect would go on continually increasing according to the same law with the velocity. Thus at a mile per second the rise of temperature would be 900°, and at 20 miles per second, which may be taken as the velocity with which meteors strike the atmosphere of the earth, 360,000°.

The temperature due to the stoppage of air at the velocity of 143 feet per second is one degree. Hence we may infer that the rise observed in the experiments was that due to the stoppage of air, less a small quantity, of which probably the greater part is owing to loss from radiation. It being also clear that the effect is independent of the density of the air, there remains no doubt whatever as to the real nature of " shooting stars." These are small bodies which come into the earth's atmosphere at velocities of perhaps 20 miles per second. The instant they touch the atmosphere their surfaces are immediately heated far beyond the point of fusion, or even of volatilization, and the consequence is that they are speedily and completely burnt down and reduced to impalpable oxides. It is thus that, by the seemingly insufficient resistance of the atmosphere, Providence secures us effectually from a bombardment which would in all probability speedily destroy all animated nature, with the exception of the fishes, which would be partly, but not altogether, protected by the water in which they swim.

The experiments to carry out and verify our previous results on the thermal effects which appear to belong to friction on large surfaces at slow velocities were made as follows :—A disc of zinc or card-board was attached to the revolving axis. An ether thermometer was attached to the disc, the bulb being near the circumference and describing a circle with a radius of about $1\frac{1}{2}$ foot. On rotating the disc at the velocity of $1\frac{3}{4}$ foot per second, as much as one-thirtieth of a degree of heat was developed.

On the Transmission of Electricity through Water. By J. B. Lindsay.

The author has been engaged in experimenting on the subject, and in lecturing on it in Dundee, Glasgow, and other places since 1831. He has succeeded in transmitting signals across the Tay, and other sheets of water, by the aid of the water alone, as a means of joining the stations. His method is to immerse two large plates connected by wires at each side of the sheet of water, and as nearly opposite to each other as possible. The wire on the side from which the message is to be sent is to include the galvanic battery and the commutator or other apparatus for giving the signal. The wire connecting the two plates at the receiving station is to include an induction coil or other apparatus for increasing the intensity and the recording apparatus. The distance between these plates he distinguished by the term " lateral distance." He found that there was always some fractional part of the power from the battery sent across the water. There were four elements on which he found the strength of the transmitted current to depend : first, the battery power; second, the extent of surface of the immersed metal sheets; third, the " lateral distance " of the immersed sheets; and, fourth, in an inverse proportion the transverse distance or distance through the water. As far as his experiments led him to a conclusion, doubling any one of the former three doubled the distance of transmission. If, then, doubling all would increase the intensity of the transmitted current eightfold, he entered into calculations to show that two stations in Britain, one in Cornwall and the other in Scotland, and corresponding stations well chosen in America, would enable us to transmit messages across the Atlantic.

On the Affections of Polarized Light reflected and transmitted by thin Plates. *By the* Rev. H. Lloyd, *D.D., F.R.S.*

When plane-polarized light is incident upon a thin plate, the reflected and transmitted pencils are, in general, *elliptically polarized.* This fact was pointed out by the author many years ago, as a result of theory; and it appears to furnish the explanation of the phenomena recently observed by Sir David Brewster, and to which he has called the attention of the Members of this Section. In the present communication the author proceeds to develope this theoretical result, and to deduce the laws according to which the elliptical polarization varies, as well with the thickness of the plate, as with the incidence.

When light incident upon a thin plate is polarized either *in the plane of incidence,* or in the *perpendicular plane,* it will continue polarized in the same plane, after the successive reflexions and refractions which it undergoes at the two surfaces of the plate; and we have only to seek the *magnitude* of the resultant vibration. The problem is different, however, when the light is polarized in *any other plane.* In this case the incident vibration must be resolved into two, in the two principal planes, and for each of these components we must know the *phases,* as well as the *magnitudes,* of the resultant vibrations, before we can estimate their joint effect. As these phases are in general different, the resulting light is elliptically polarized.

When the media are the same on the two sides of the plate, the *difference of phase* of the two component vibrations (upon which the character of the resulting light mainly depends) is given by the formula

$$\tan\Delta = \frac{(v^2-w^2)\sin\alpha}{1-(v^2+w^2)\cos\alpha+v^2w^2};$$

in which α is the phase due to the retardation of the wave, which has passed once to and fro within the plate; and v and w the coefficients of the reflected vibrations, for light polarized in the plane of incidence, and in the perpendicular plane, respectively. It follows from this, that Δ varies with α, and therefore with the thickness of the plate; and that, in the phenomena of the rings, it will *go through all its values within the limits of each ring.*

Δ vanishes, when $\alpha=m\pi$, *i. e.* both at the *bright,* and at the *dark* rings; and accordingly the light at the former is *plane-polarized.*

On the other hand, Δ is a *maximum,* relatively to the thickness of the plate, when

$$\cos\alpha = \frac{v^2+w^2}{1+v^2w^2};$$

and the maximum value is given by the formula

$$\tan\Delta = \frac{v^2-w^2}{\sqrt{(1-v^4)(1-w^4)}}.$$

Substituting for v and w their well-known values in the former of these formulæ, we find

$$4\cot^2\frac{\alpha}{2} = (\mu+\mu^{-1})^2+(\rho-\rho^{-1})^2;$$

in which μ is the refractive index, and ρ the ratio of the cosines of incidence and refraction. It follows from this, that $\cot\frac{\alpha}{2}$ increases, from $\frac{1}{2}(\mu+\mu^{-1})$ at a perpendicular incidence, to infinity when the incidence is most oblique; and that, in a plate of varying thickness, the points of maximum difference of phase commence near the middle of an interval, and approach indefinitely to the dark rings as the incidence approaches to 90°.

A similar discussion of the second formula shows that the maximum difference of phase *increases continuously with the incidence,* being nothing at a perpendicular incidence, and greatest when the incidence is most oblique. The *absolute maximum* is given by the formula

$$\cot \Delta = \frac{2\mu}{\mu^2 - 1}.$$

For ordinary flint-glass, $\Delta = 26° \, 0'$.

The difference of phase in the two component portions of the polarized beam is *the same in the reflected and in the transmitted pencils.*

There is no difficulty in extending the investigation to the more general case, in which the media on the two sides of the plate are of *unequal refractive densities*; but in this case the law last stated no longer holds. The general formulæ for the *intensity* explain not only the phenomena observed by Arago and by Sir David Brewster, but likewise indicate some results hitherto unnoticed.

On the Mixture of the Colours of the Spectrum. By Prof. J. C. Maxwell.

The author described his apparatus for obtaining a uniform field, illuminated by the light of any one or more definite portions of the spectrum, and comparing this mixture with a field of white light in contact with it. The experiments consisted in obtaining perfect equality between a combination of three definite portions of the spectrum and this white light. The relations of these portions are then ascertained by mathematical treatment of the equations so obtained, and it results that Newton's "circle of colours" is found to be really two sides of a triangle; red, yellow-green, and blue being the angular points, and yellow being on the side between red and green. The extreme red and violet form small portions of the third side, of which the middle part representing purple is wanting in the spectrum.

The peculiar dimness of the spectrum near the line F, as described to the Section in 1856, was further investigated, and shown to be more marked to the author's eyesight than to that of others. It results from this that a mixture may be formed, which appears green to one eye and red to another, and this was found experimentally true.

These results are only part of a complete investigation of the colours of the spectrum, of which the experimental portion is considerably advanced and will shortly be published.

On certain Laws of Chromatic Dispersion.
By Mungo Ponton, *F.R.S.E.*

This paper is an attempt to trace the laws regulating the diminution of the wave-lengths, corresponding to the fixed lines of Fraunhofer, in passing through various refractive and dispersive media. If U be the length of the undulation, corresponding to any line, in the free ether, and u its length after being subjected to the action of the medium, the relation between U and u may be expressed thus: $\frac{U}{\epsilon} \alpha - \pm x = u$, or $\epsilon\,(u + \alpha \pm x) = U$. Here ϵ and α are constant for the medium and temperature, while the quantity x, which is comparatively small, is peculiar to each wave. These quantities x represent that displacement or extrusion of the fixed lines, from their normal relative positions in the pure diffracted spectrum, which constitutes the *irrationality* of the various refracted spectra; and they are accordingly termed the *extrusions* of the fixed lines. Thus each medium is regarded as having a refractive, a dispersive, and an extrusive power, peculiar to itself at a given temperature.

The constant ϵ is found thus: B, C, D, &c. representing the normal wave-lengths corresponding to the fixed lines, and b, c, d, &c. these wave-lengths after refraction, calling $(3\,B + 2C + D) - (F + 2G + 3H) = \Delta$ and $(3b + 2c + d) - (f + 2g + 3h) = \delta$, then is $\epsilon = \frac{\Delta}{\delta}$.

The constant α is found thus: S being the sum of the normal wave-lengths corresponding to the 7 lines, and s their sum after refraction, then is $\alpha = \frac{1}{7}\left(\frac{S}{\epsilon} - s\right)$.

The values of α and of log ϵ for the different media are given in Table I.

From these two constants, a second series of refracted wave-lengths may be calculated, thus: $\frac{B}{\epsilon}-\alpha=b_2$, $\frac{C}{\epsilon}-\alpha=c_2$ &c., which will represent what the refracted wave-lengths would be, were the medium free from irrationality. This series is presented in Table III.; and from it, compared with the series found by observation, as exhibited in Table II., the values of x, or the extrusions for the different media, are deduced, as exhibited in Table IV.

In the larger proportion of the media which have been examined, these quantities x are governed by certain determinate laws. The departures from these laws, presented by several media, are shown to be traceable to errors of observation; and they wholly disappear when the numbers are brought under the dominion of the more general law, subsequently determined. Then only two exceptions remain—the solution of muriate of zinc, and the oil of cassia. The discrepancy, in the former case, it is suggested, is probably due to errors which the observer himself (Powell) suspects to exist in his determinations,—the discrepancy in the case of the oil of cassia being probably traceable to a similar cause.

The extrusive force, on which the irrationality depends, exhibits itself in the form of a transfer of motive energy, from the terminal to the central parts of the spectrum. The undulations, corresponding to the lines D, E, and F, are a little *less* retarded than they would otherwise be, and their wave-lengths within the medium are accordingly a little less shortened. Hence for D, E, and F the formula is $\frac{U}{\epsilon}-\alpha+u_x=u$. The undulations, corresponding to B, C, G, and H, are a little *more* retarded than they would otherwise be, and their wave-lengths within the medium more shortened; so that for these four the formula is $\frac{U}{\epsilon}-\alpha-u_x=u$, the positive and negative values of x balancing each other. Hence twice their sum, or 2X, is reckoned the measure of the extrusive power of the medium.

Every medium accordingly presents two nodes where the extrusion is nil and passes from positive to negative. The upper node lies between C and D, and probably occupies the position of the mean wave; the lower lies between F and G, and near G. The only permanent exception is the oil of cassia, in which the lower node falls a little below G.

All regular media present the following relation: $(3b_x+2c_x-d_x)=(3h_x+2g_x-f_x)$. It is proposed to call this "the Semel-bis-ter law." Hence, if $K=(B+C+G+H)-(D+E+F)$ and $Q=(b+c+g+h)-(d+e+f)$, the extrusive power may be expressed thus: $\frac{K}{\epsilon}-(Q+\alpha+2X)=0$.

If the extrusions be taken in pairs, equidistant from the centre e_x, and if the difference between b_x and h_x be denoted by δ, that between c_x and g_x by δ_2, and that between d_x and f_x by δ_3, then the differences between each pair of these three quantities δ_1, δ_2, and δ_3 constitute a progression of the form ζ, 2ζ, 3ζ, the quantity ζ varying with the medium and temperature. It is proposed to call this "the law of the equicentral common difference."

The series of refracted wave-lengths b_2, c_2, d_2, &c. having been calculated, as in Table III., the refractive indices corresponding to them may be found from the formula $\frac{B}{b_2}=\mu_2 B$, $\frac{C}{c_2}=\mu_2 C$, &c. This series of indices $\mu_2 B$, $\mu_2 C$, &c. is what the medium would present, had it no extrusive power; and the differences between these and the observed indices show what portion of the latter is due to that property. These two sets of indices present nodes, corresponding to those of the extrusions; and it is shown to be a general law, that the refractive indices, corresponding to the nodes of the extrusions, coincide with the nodes of the two sets of refractive indices. It is proposed to call this "the law of coincident nodes."

The apparent exceptions to these laws are then pointed out, and the probability of their being all due to errors of observation is discussed.

The product of the two constants, or $\epsilon\alpha$, deducted from each of the normal wave-lengths, shows how much each normal is shortened in passing through the medium, from the operation of the dispersive power alone. The *actual* loss of length, being represented by $\epsilon\alpha$, is the same for all waves; consequently it tells more on those waves which are primarily shorter. Hence the numbers representing the loss of length sustained by each wave in proportion to its primary length, from the operation of the dispersive power alone, are in inverse proportion to the primary wave-lengths. These rateable losses of wave-length, multiplied by the second series of refractive indices μ_2 B, μ_2 C, &c., exhibit the proportion of each index due to the dispersive power alone. These points are exemplified by the case of the bisulphuret of carbon.

In *different* media, the loss of length, sustained by any one wave through the operation of the dispersive power alone, is proportional to the constant α, which may accordingly be regarded as its measure.

The effects of change of temperature are illustrated by the two cases of oil of anise, and oil of cassia, for which alone sufficient experimental data exist; and it is shown to be probable, that, in the same medium, the values of ϵ are in the inverse orders of the temperatures, and their differences proportional to the differences of temperature; also that, in different media, in which the value of ϵ is nearly the same, the fall in that value is proportional to the rise of temperature.

The constants ϵ and α, being influenced only by the mutual relations of the extrusions, and not by their absolute values, are consistent with an indefinite number of sets of indices of refraction; so that the indices may always be altered in a certain manner, without altering the constants. It is then shown, that the conservation of the total *vis viva* of the normal wave-lengths depends on the constants ϵ and α, and a third constant η, thus:

$$\epsilon\alpha\left\{\frac{B}{(B-\epsilon b)\pm\eta}+\frac{C}{(C-\epsilon c)\pm\eta}+\frac{D}{(D-\epsilon d)\pm\eta}+\frac{E}{(E-\epsilon e)\pm\eta}+\frac{F}{(F-\epsilon f)\pm\eta}\right.$$
$$\left.+\frac{G}{(G-\epsilon g)\pm\eta}+\frac{H}{(H-\epsilon h)\pm\eta}\right\}=S.$$

To find η, call the sum of the series $\frac{B}{B-\epsilon b}+\frac{C}{C-\epsilon c}+\&c.=\Sigma$, and call $\frac{S}{\Sigma}=\epsilon\acute{\alpha}$, then η is the difference between $\epsilon\alpha$ and $\epsilon\acute{\alpha}$. If $\alpha>\acute{\alpha}$, then η is +; if $\acute{\alpha}>\alpha$, then η is −, and in either case is constant for the medium and temperature. It is always possible to find a positive value of X which shall render $\eta=0$. Calling this limiting value $\acute{X}$, then is $\acute{X}=\alpha\frac{4(B+C+G+H)-3(D+E+F)}{S}$.

The logarithm of this multiple of α is $\bar{2}\cdot4216417$.

The effects of raising the normal wave-lengths to different powers are next examined. It is shown that, in every case, there is a certain power at which the extrusions are reduced to a *minimum*, and that these lowest values are so small that they may be referred to errors of observation. There is thus always a certain exponent, which may be applied to the normals, which will extinguish the extrusions, so rendering the relation between the wave-length λ and its refractive index μ capable of being expressed by this general formula: $\mu=\lambda_n\div\frac{\lambda^n}{\epsilon_n}-\alpha_n$. This it is proposed to call "the exponential law of dispersion."

The value of the exponent n depends on the relation which the irrationality bears to the dispersive power, or to the length of the spectrum. Expressing this relation thus, $\frac{2X}{\alpha}=\rho$, the following equation is universally applicable: $\frac{\rho}{n-1}=$ constant.

By analysing the observations, the value of this constant is found to be nearly 0·0092593, and its reciprocal 10·8. These values are accordingly assumed, but subject to future correction. Hence 11·8 is the highest limit of the value of n, being that which the medium would have if $2X=\alpha$. The lowest value of n, $=1$, subsists when $\alpha=0{\cdot}0092593$ and $2X=0$.

As the value of ρ may be obtained, with tolerable accuracy, from any set of observations *which are approximately correct*, the value of n may be found from the equation $10{\cdot}8\rho+1=n$ with sufficient accuracy for calculating the indices; and it is unnecessary, in using this exponent, to go beyond the first place of decimals. The exponents for the various media, calculated from this equation, are given in Table I. The constants ϵ_n and α_n are determined from the nth power of the normals, in the same manner as ϵ and α are determined from their first power. These values are also given in Table I.

The logarithms of the normals for each exponent from 1 to 3·5 are given in Table V., the normals adopted being those determined by the method explained in the separate paper on that subject.

The indices of refraction for the various media, as calculated from the general formula $\mu=\lambda^n \div \frac{\lambda^n}{\epsilon_n} - \alpha_n$, are given in Table VI.; the observed indices in Table VII.; and the differences between the two in Table VIII.

These tables are next minutely analysed, the observations being for this purpose classified. From this analysis it appears that, as respects the observations of Fraunhofer and Rudberg, the agreement between the observed and calculated indices is so close as to leave no doubt of the accuracy of this exponential law; that as regards the larger proportion of Powell's observations, the agreement is equally satisfactory; but that in some of these the discrepancies are considerable. It is proved, however, by comparing the different observations together, that these discrepancies can be attributed only to errors of observation. For example, it is pointed out that while Fraunhofer's two sets of observations on water agree almost perfectly with the law, Powell's single observation on the same medium exhibits a very considerable discrepancy, which can be attributed to nothing but experimental error. It is next shown that Powell's observation on oil of cassia at temp. 14° Cent. presents a discrepancy from the law scarcely exceeding that of his observation on water, so that it also may be fairly attributed to experimental error. But his observations on oil of cassia at temp. 10° and 25° present the greatest discrepancies of all from the law; and this difference between the results obtained for the same medium at these different temperatures can be due to nothing but experimental errors, seeing it is the observation at the intervening temperature that is least discordant with the law. Thus, if the larger discrepancies, in the case of the oil of cassia at the extreme temperatures, be traceable to errors of observation, all the smaller discrepancies in other media may be fairly attributed to the same cause.

When the indices of all the media have been corrected by the exponential law, then the whole become quite regular, as respects the position of the nodes of the extrusions and the relations which these quantities bear to each other, with the single exception of the oil of cassia; and as considerable errors of observation are shown to exist in that case, it appears not improbable that this exception might be removed by a more careful repetition of the observations.

The exponential law is then contrasted with the hypothesis of M.Cauchy,—namely, "that the differences between the refractive indices of the medium are to each other, very nearly, as the differences between the reciprocals of the squares of the normal wave-lengths. Or the refractive indices are each composed of two terms, whereof one is constant for the medium and temperature, the other reciprocally proportional to the squares of the normal wave-lengths." The indices calculated by Powell on the basis of this law, are compared with those calculated on the basis of the exponential law, and the differences are presented in Table IX. The result is shown to be greatly in favour of the exponential law. In the case of Fraunhofer's observations, the rate in its favour, as compared with the law of M. Cauchy, is as 2 to 1; in Rudberg's observations as 4 to 3, in Powell's as 10 to 7, and on the aggregate nearly as 3 to 2. In the particular and important case of the bisulphuret of carbon, the rate exceeds 5 to 1.

The two laws are next examined and compared, as respects their principle and physical interpretation. The law of M. Cauchy merges together all the three phenomena—the refraction, the dispersion, and the irrationality, as if they were all due to one and the same cause; and it seeks, by a general formula, to dispense with observation to a certain extent, and to find the refractive indices of four of the fixed lines, from those of the other three being given by observation. In the exponential law, on the other hand, the refraction, the dispersion, and the irrationality are regarded as distinct and independent phenomena, referable to different causes; in evidence of which it is remarked that a low refractive power may consist with a high dispersive and extrusive power, or *vice versâ*. To arrive with accuracy at the exponent of the normals for any medium and temperature, it is advisable to know, from observations on all the seven lines, made with an approximate degree of correctness, the refraction, the dispersion, and the irrationality; seeing the exponent depends on the relation of the irrationality to the dispersion.

A pretty close approximation to the value of the exponent and the two relative constants may be made, from having given only the indices of the two extreme, and one of the central lines; and from these the other four indices might thus be found. But there is no advantage in proceeding in this imperfect manner. Observations on the whole seven lines can never be dispensed with in practice; and as these tend mutually to check one another, it will always be found more expedient to take the whole seven into account in the determination of the exponent and the constants. The exponential law should therefore be regarded less as a substitute for observation, than as a method of reducing the observations, when made within certain limits of accuracy, under the dominion of law, and of thus rendering their accuracy more perfect. The essential difference between the law of M. Cauchy and the exponential law, then, is, that the latter substitutes a variable exponent, capable of determination, for the squares of the normals employed in the former.

The constant ϵ represents the effects of the refractive power alone, such as they would appear in achromatic combinations of prisms. It shows how much the waves are shortened by the mere increased proximity of the ethereal particles, or centres of elasticity, within the medium; and as it affects all the waves rateably, it may subsist without either dispersion or irrationality. In so far as this property is concerned, the waves, on entering the medium, embrace, in their length, the same number of ethereal particles as they did in the free ether.

The constant α represents the effects of the dispersive power alone, which is attributed to the medium increasing the persistence of the ethereal particles in their normal positions, beyond that degree in which it would be augmented by their mere mutual approximation. It is supposed that, by this action, a certain definite number of ethereal particles are excluded from the length of each wave, so as to cause all of them to be shortened by the same definite amount. Thus the shorter waves are more shortened, in proportion to their primary length, than are the longer waves. These consequently exhibit unequal degrees of refrangibility, and are accordingly, on issuing from the medium, dispersed.

In explanation of the extrusive property, to which the irrationality is attributed, two views are suggested. Evidencing, as they do, an apparent transfer of motive energy from the extreme to the central parts of the spectrum, so that the central waves are less refracted, and the extreme waves more refracted, than they would otherwise be, the effects of the extrusive power present, as respects distribution, a conformity with the degrees of brightness of the spectrum; for all spectra are brighter towards the centre, and fade off on either side. This circumstance indicates that, at the recipient surface, the amplitudes of the individual vibrations embraced in the waves are greatest towards the centre. Now the action of the medium may be such as to lessen the amplitude of the vibrations, in all the waves, by a certain definite amount—the rapidity of vibration (consequently the refrangibility of the wave) being increased in the same proportion. But the waves whose individual vibrations have the greatest amplitude will, by such a constant force, be less affected, in proportion to the primary amplitude, than are the waves whose individual vibrations are of smaller amplitude. The consequence will be, that the latter will appear to have their refrangibility increased in a slightly greater degree than the former; so that the waves corresponding to the lines B, C, G, and H will be further removed towards the violet extremity of the spectrum, and those corresponding to the lines D, E, and F less removed towards that extremity, than they would be in the absence of the extrusive property.

As an alternative to this view, it is suggested that these slight alterations in the rapidity of the individual vibrations may be due to a sympathetic action between the vibrations of the ponderable atoms of the medium and those of the ethereal particles, resembling the sympathy of pendulums, in virtue of which some of the latter are slightly increased, and others slightly diminished in rapidity, beyond what they would otherwise be.

In conclusion, the attention of the British Association is invited to the unsatisfactory state of a considerable number of the observations, and to the necessity of having these repeated, and the whole series further extended, more especially the observations on the same medium at different temperatures.

List of Tables presented by the author in illustration of the paper.

TABLE I. Elements of Calculation.
„ II. Internal wave-lengths calculated from the observed Indices of Refraction.
„ III. Internal wave-lengths freed from the Extrusions.
„ IV. The Extrusions.
„ V. Logarithms of the wave-lengths of the fixed lines for each exponent from 1 to 3·5.
„ VI. Indices of Refraction calculated from the Exponential Law.
„ VII. Observed Indices of Refraction.
„ VIII. Differences between observed Indices and those calculated by the Exponential Law.
„ IX. Differences between observed Indices and those calculated by the law of M. Cauchy, with comparison of results.

On the Law of the Wave-lengths corresponding to certain points in the Solar Spectrum. By MUNGO PONTON, *F.R.S.E.*

This paper commences by tracing, to their basis, the numbers given by Sir Isaac Newton to express the wave-lengths corresponding to the borders of the coloured spaces of the spectrum. There is first obtained, by geometrical construction, the primary series 1·2857, 1·1428, 1·0714, 0·9643, 0·8571, 0·7714, 0·7232, 0·6429, the length of the mean wave being=1. Of these numbers the cube roots of the squares are taken, giving the series 1·1824, 1·0931, 1·0470, 0·9761, 0·9023, 0·8411, 0·8057, 0·7449. The length of the mean wave being experimentally ascertained to be 0·00002247 decimal parts of an English inch, the Newtonian wave-lengths are found by multiplying the second of the above series by this quantity. They stand thus:

0·00002657
Red
0·00002456
Orange
0·00002353
Yellow
0·00002193
Green
0·00002028
Blue
0·00001890
Indigo
0·00001812
Violet
0·00001674

This is the estimate usually given of these wave-lengths, in the English works on Optics.

The two series given by Fraunhofer to express the wave-length corresponding to his seven principal fixed lines, are then stated in decimal parts of a *French* inch, as under:—

	B	C	D	E	F	G	H
I.	0·00002541,	0·00002425,	0·00002175,	0·00001943,	0·00001789,	0·00001585,	0·00001451
II.	2541	2422	2175	1945	1794	1587	1464
		+3		−2	−5	−2	−13

It is mentioned that the only approach to a law regulating these numbers, hitherto ascertained, is an approximation, in the *second* series, to the relation

$$\left(\frac{1}{F}\right)^2-\frac{1}{2}\left\{\left(\frac{1}{B}\right)^2+\left(\frac{1}{H}\right)^2\right\}=0.$$

It is then shown that the following relations subsist, with sufficient accuracy to admit of their being fairly assumed : viz. $B^5=D^6$ and $B^7 D=E^{11}$,—the E being that of the *first* series. Another advantage, presented by the first series, is then pointed out. The whole of the wave-lengths being formed into an equicentral series of fractions, thus, $\frac{B}{H}, \frac{C}{G}, \frac{D}{F}, \frac{B}{E}, \frac{C}{E}, \frac{D}{E}, \frac{E}{F}, \frac{E}{G}, \frac{E}{H}$, in which each greater is divided by each less; and these being arranged in the order of their magnitude, the following relations are traced: viz.,

$$\frac{B}{H}=\frac{C}{G}+0{\cdot}22', \ \frac{C}{G}=\frac{B}{E}+0{\cdot}22', \ \frac{B}{E}=\frac{E}{F}+0{\cdot}22', \text{ and } \frac{B}{H}+\frac{C}{E}=3.$$

The series based on these relations stands thus :

	Logs.	Numbers.		Differences.
$\frac{B}{H}$	0·2436268	1·752374		
$\frac{C}{G}$	0·1847346	1·530152		0·222222′
$\frac{E}{H}$	0·1270422	1·339807	0·190345	0·222222′
$\frac{B}{E}$	0·1165846	1·307930	0·031877	
$\frac{C}{E}$	0·0960845	1·247626	0·060304	
$\frac{F}{G}$	0·0886501	1·226451	0·021175	
$\frac{D}{F}$	0·0848012	1·215630	0·010821	0·222222′
$\frac{D}{E}$	0·0490882	1·119665	0·095965	
$\frac{E}{F}$	0·0357130	1·085708	0·033957	0·666666′

The differences between this series and the corresponding series deduced from the observed values, are shown to be so trifling that they may be fairly attributed to errors of observation.

The wave-lengths, as calculated from this series, are then compared with the observed wave-lengths, as in the following Table :—

	Calculated.	Observed.	Differences.	
B	2540844	2541000		−000156
C	2423694	2425000		−001306
D	2175112	2175000	+0000112	
E	1942645	1943000		−0000355
F	1789289	1789000	+0000289	
G	1583957	1585000		−0001043
H	1449944	1451000		−0001056

The differences here presented being smaller than the least of the differences between the corresponding members of the two observed series, the relations on which the calculated values are based are submitted as being in the highest degree probable. These relations present the advantage of rendering the whole of the wave-lengths deducible from that of either B or D.

The following Table exhibits the *relative* wave-lengths, referred to that of B as unity :—

	Logarithms.	Numbers.
	C $\bar{1}$·9794999	0·9538934
	D $\bar{1}$·9325036	0·8560588
	E $\bar{1}$·8834154	0·7645667
	F $\bar{1}$·8477024	0·7042103
	G $\bar{1}$·7947653	0·6233979
	H $\bar{1}$·7563732	0·5706545
Mean wave	M $\bar{1}$·9701116	0·9334940

It is next pointed out that the Newtonian wave-lengths corresponding to the lines of junction of the colours, are not reconcilable with the wave-lengths corresponding to the fixed lines of Fraunhofer, and that this discrepancy arises from the former having been deduced from an impure spectrum. It is shown, however, that if the primary series on which Newton's numbers are based be assumed without subjecting it to the process of taking the cube roots of the squares, and if it be multiplied by the mean wave-length in decimal parts of a French inch, it will present a series agreeing better with Fraunhofer's wave-lengths. The result is exhibited in the following Table, omitting the prefixed ciphers :—

	Borders of Colours.		Fixed Lines.
	27107		B 2540844
Red			C 2423694
	24094		
Orange		Mean wave	M 2371900
	22588		
Yellow			D 2175112
	20330		
Green			E 1942645
	18070		
Blue			F 1789289
	16264		
Indigo			G 1583957
	15247		
Violet			H 1449944
	13554		

This series makes the interval between the extreme violet and the extreme red as 1 to 2, corresponding to the musical octave.

It is in conclusion suggested that fresh observations should be made, under the sanction of the British Association, on the wave-lengths corresponding to the borders of the coloured spaces in the diffracted spectrum, to ascertain if they be accurately represented by the above series; so that the existing error, in regard to the estimated values of those wave-lengths, may no longer be perpetuated.

On the Production of Colour and the Theory of Light. *By* John Smith, *M.A., of Perth Academy, Perth.*

The author had come to the belief, by means of experiments, that colour is produced by alternate light and shade in various proportions. To prove this, he caused a white ray to revolve at various speeds on a black surface. His first experiment was to move a slip of white card-board over a black surface. By this motion he obtained a distinct blue; afterwards, in different weather, the same thing produced a purple. He then made a disc with five concentric rings. One ring was painted one-third black, the rest of the ring being white; the next ring was two-thirds black and one-third white; the next was three-fourths black and one-fourth white, and the fifth half black and half white. This disc, when made to revolve, became completely coloured; there were no more blacks or whites visible, but five rings of different colours. On a bright day with white clouds in the sky, the

1st ring was of a light green: much yellow.

2nd ring purple: very blue.

3rd ring nearly as first.

4th ring purple, darker than the 2nd.

5th ring pink.

By means of excentric motions a great variety of colours were obtained; amongst others, a pure red and various shades of purple, pink, yellow, and blue. The number of discs tried were very great, each disc having on it a different proportion of black and white.

The author produced the same results by cutting out spaces in the white card, and causing it to revolve on a black surface. He produced also similar phenomena by causing these figures to revolve when held perpendicularly, and to take the appearance of coloured solids. He also caused these colours to be reflected on a white surface from the revolving disc. These experiments, and the views drawn from them, were used for the purpose of giving a theory of the prism, to be published in detail. It was by such processes that the author was led to believe that he had demonstrated that colour is produced by a mixture of light and shadow at various intervals; and at last he was satisfied that the experiments were original, and not explicable by the present recognized laws.

He concluded in these words nearly:—Remarkable as these experiments are, they are not more remarkable than the results they lead to.

They prove the homogeneity of the ether.

They prove the undulatory hypothesis, but oppose the undulatory theory.

They show the necessity of introducing a negative element into the theory of colour, or that colour is the effect of two coordinate sensations—a positive and a negative.

They enable us to dispense with the different refrangibilities of the rays of light, taught by Newton.

They remove the necessity for the supposition of different lengths of waves or of a disposition in matter to produce waves of different lengths.

They help to explain many of the phenomena of what is called the polarization of light.

They give a new explanation of prismatic refraction, and explain in a plain and simple manner many very interesting natural phenomena.

Startling, he said, as these conclusions are, to those who are conversant with the subject of light, he thought he was perfectly warranted in drawing them from his experiments.

On Radiant Heat. By B. Stewart, *M.A.*

In addition to the facts communicated at the last Meeting, the author mentioned that he had since examined the nature of the heat emitted by heated rock-salt, and found that it possessed very great wave-length. He had also shown that table-salt, pounded saltpetre, and pounded sulphate of potassa were white for heat; while pounded sugar, pounded alum, and pounded citric acid were black. The inference is that, could saltpetre or sulphate of potassa be obtained in crystals large enough, they would be diathermanous like rock-salt.

He had also, in endeavouring to ascertain the law of particle radiation, asked himself the question, What would be the consequence if the ultimate particles of different bodies radiated the same quality of heat at the same temperatures? and he had calculated that were there a group of bodies possessing this common property, viz. having particles which radiate the same quality of heat at the same temperature, it would follow that if we were to take slices of such bodies of thicknesses such that they all permitted to pass the same proportion of heat of any one kind, then they would also all pass the same proportion of heat of any other kind. There are some indications that rock-crystal and glass crystal form one such group, and that citric acid and tartrate of potash and soda form another.

On recent Theories and Experiments on Ice at its Melting-point. By Professor J. Thomson, *M.A.*

The object of this paper was to discuss briefly the bearings of some of the leading theories of the plasticity and other properties of ice, at or near its melting-point, on speculations on the same subject advanced by the author *; and especially to offer

* Proceedings of the Royal Society, May 1857: also British Association Proceedings, Dublin Meeting, 1857.

an explanation of an experiment by Prof. James D. Forbes which had been advanced as in opposition to the author's theory.

He referred at the outset to the fact pointed out by Mr. Faraday in 1850 *, that two pieces of moist ice, when placed together in contact, will unite together, even when the surrounding temperature is such as to keep them in a thawing state. Mr. Faraday had attributed this phenomenon to a property which he supposed ice to possess, of tending to solidify water in contact with it, and of tending more strongly to solidify a film or a particle of water when the water has ice in contact with it on both sides, than when it has ice on only one side.

Dr. Tyndall had subsequently adopted this fact as the basis of a theory by which he proposed to explain the viscidity or plasticity of ice, or its capability of undergoing change of form, which had previously been known to be the property in glaciers in virtue of which their motion down their valleys is produced by gravitation. Designating Mr. Faraday's fact under the term "*regelation,*" Dr. Tyndall, in the theory referred to, described the capability of glacier ice to undergo changes of form, as being not true viscosity, but as being the result of vast numbers of successively occurring minute fractures, changes of position of the fractured parts, and *regelations* of those parts in their new positions. The terms *fracture* and *regelation* had then come to be the brief expression of Dr. Tyndall's idea of the plasticity of ice.

The author, Professor James Thomson, considered, on the contrary, that if, in a material having no inherent property of plasticity independent of fracture, any steady force applied (such as the force of gravity acting on a glacier) be sufficient to cause fracture, the substance must go down suddenly until a position of repose is attained, and that the addition of a principle of reunion (such as "regelation") cannot have a tendency to reiterate the fractures after such position of repose has been attained.

His own theory, he stated, might be sketched in outline as follows :—If to a mass of ice at its melting-point, pressures tending to change its form be applied, there will be a continual succession of pressures applied to particular parts—liquefaction occurring in those parts through the lowering of the melting-point by pressure—evolution of the cold by which the so melted portions had been held in the frozen state—dispersion of the water so produced in such directions as will afford relief to its pressure—and recongelation, by the cold previously evolved, of the water on its being relieved from this pressure : and the cycle of operations will then begin again ; for the parts recongealed must in their turn, through the yielding of other parts, receive pressures from the applied forces, thereby to be liquefied, and then to go through successive processes as before. He thus considered that the plasticity consists not of fracture and regelation, but essentially of melting by pressure and recongelation on relief from pressure.

Professor James D. Forbes † had adopted the view, that the dissolution of ice is a gradual, not a sudden process, and so far resembles the tardy liquefaction of fatty bodies, or of the metals which in melting pass through intermediate stages of softness or viscosity. He thought that ice must be essentially colder than water in contact with it ; and that, between the ice and the water, there is a film having its temperature varying from side to side, which may be called plastic ice, or viscid water ; and that through this film heat must be constantly passing from the water to the ice, and the ice must be wasting away, though the water be what is called ice-cold. Professor Forbes had stated afterwards, as a modification of this supposition, that if a small quantity of water be enclosed in a cavity in ice, it will undergo a gradual "*regelation,*" or that the ice will in this case be increased instead of wasted. In reference to this, Professor J. Thomson put forward the case of a medium quantity of water, in contact with a medium quantity of ice, without addition or abstraction of heat ; and stated that, were the idea of Professor Forbes on this subject correct, the result in this case ought to be that the water and ice should ultimately pass into the state of uniform viscidity ; for Professor Forbes's own words distinctly deny the permanence of the water and ice in contact in their two separate states, as he says, "bodies of different temperatures cannot continue so without interaction. The water *must* give off heat to the ice, but it spends it in an insignificant thaw at the surface." Thus then it would follow from the admission of Professor Forbes's views,

* See Faraday's Researches in Chemistry and Physics, 1859.

† See Forbes 'On the Recent Progress and Present Aspect of the Theory of Glaciers,' forming the introduction to a volume of Occasional Papers on the Theory of Glaciers, 1859.

that viscid water could be produced in any large quantities desired, like as it is supposed to be produced in small quantities in the hypothetical thin film at the surface of hard ice—an inference which is plainly contrary to all experience, as no person has ever, by any peculiar application of heat to, or withdrawal of heat from, a quantity of water, rendered it visibly and tangibly viscid, so that it could be poured in a thick state like honey. We even know that water may be cooled much below the ordinary freezing-point, and yet remain fluid.

Professor Forbes, however, although, in his recent writings, maintaining the views just alluded to, had not rejected the author's theory as altogether unfounded. He had rather admitted that it points out some of the causes which may impart to a glacier a portion of its plasticity; and also that it meets with verification to some extent in the moulding of ice subject to rapid alternations of pressure under the Bramah's press.

Mr. Faraday, in his recently published 'Researches in Chemistry and Physics,' had adhered to his original mode of accounting for the phenomenon he had observed, and had developed farther the explanation of his ideas on the subject, and adduced examples of the action of numerous other substances in passing from the liquid to the solid, or from the solid to the liquid state, and also in passing from the liquid to the gaseous state. Professor J. Thomson, however, considered that the general bearing of all the phenomena adduced, is not to sustain the view of Mr. Faraday, but to show that the particles of a substance, when existing all in one state only, and in continuous contact with one another, or in contact only under special circumstances with other substances, experience *a difficulty of making a beginning of their change of state*, whether from liquid to solid, or from liquid to gaseous, or probably also from solid to liquid. He did not admit that anything had been adduced showing a like difficulty as to their undergoing a change of state when the substance is present in the two states already, or when a beginning of the change has already been made. He believed that when water and ice are present together, their freedom to change their state on the slightest addition or abstraction of heat is perfect. He therefore could not admit the validity of Mr. Faraday's mode of accounting for the phenomena of so called *"regelation."*

Thus the fact of "regelation," which Professor Tyndall had taken as the basis of his theory for explaining the plasticity of ice, did, in the author's opinion, as much require explanation as the plasticity of ice which it was applied to explain. The two observed phenomena, namely, the tendency of two separate pieces of ice to unite when placed in contact, and the plasticity of ice, are, he believed, cognate results of a common cause, and are explained by the theory he had himself offered.

The experiment by Professor Forbes adduced in opposition to the author's theory was to the following effect:—

Two slabs of ice, having their corresponding surfaces ground tolerably flat, on being suspended in an atmosphere a little above the freezing-point, upon a horizontal glass rod passing through two holes in the plates of ice, so that the plates may hang vertically, and in contact with one another, were found in a few hours to be united so as to adhere strongly together. This Professor Forbes had supposed would prove that mere contact without pressure is sufficient to produce the union of two pieces of moist ice. The author, on the contrary, explained the fact by the capillary forces of the film of interposed water as follows:—*First*, the film of water between the two slabs—being held up against gravity by the capillary tension, or contractile force of its free upper surface, and being distended besides, against the atmospheric pressure, by the contractile force of its free surface round its whole perimeter—except for a very small space at bottom, from which water trickles away, or is on the point of trickling away—exists under a pressure which, though increasing from above downwards, is everywhere, except at that little space at the bottom, less than atmospheric pressure. Hence the two slabs are urged towards one another by the excess of the external atmospheric pressure above the internal water pressure, and are thus pressed against one another at their places of contact by a force quite notable in amount.

Secondly, the film of water existing, as it does, under less than atmospheric pressure, has its freezing-point raised in virtue of the reduced pressure; and it would therefore freeze even at the temperature of the surrounding ice, namely, the freezing-point for atmospheric pressure. Much more will it freeze in virtue of the cold given out in the melting by pressure of the ice at the points of contact, where, from the first two causes named above, the two slabs are urged against one another.

The freezing of ice to flannel, or to a worsted glove on a warm hand, was, in his opinion, to be attributed partly to capillary attraction acting in similar ways to those just stated; but he considered that, in many of the observed cases of this phenomenon, there are also direct pressures from the hand, or from the weight of the ice, or from other like causes, which must be supposed to increase the rapidity of the moulding of the ice to the fibres of the wool.

On Electrical "Frequency." *By* Professor W. Thomson, *LL.D., F.R.S.*

Beccaria found that a conductor insulated in the open air becomes charged sometimes with greater and sometimes with less rapidity, and he gave the name of "frequency" to express the atmospheric quality on which the rapidity of charging depends. It might seem natural to attribute this quality to electrification of the air itself round the conductor or to electrified particles in the air impinging upon it; but the author gave reasons for believing that the observed effects are entirely due to particles flying away from the surface of the conductor, in consequence of the impact of *non-electrified* particles against it. He had shown in a previous communication that when no electricity of separation (or, as it is more generally called, "frictional electricity," or "contact electricity") is called into play, the tendency of particles continually flying off from a conductor is to destroy all electrification at the part of its surface from which they break away. Hence a conductor insulated in the open air, and exposed to mist or rain, with wind, will tend rapidly to the same electric potential as that of the air, beside that part of its surface from which there is the most frequent dropping, or flying away, of aqueous particles. The *rapid charging* indicated by the electrometer under cover, after putting it for an instant in connexion with the earth, is therefore, in reality, due to a *rapid discharging* of the exposed parts of the conductor. The author had been led to these views by remarking the extreme rapidity with which an electrometer, connected by a fine wire with a conductor insulated above the roof of his temporary electric observatory in the island of Arran, became charged, reaching its full indication in a few seconds, and sometimes in a fraction of a second, after being touched by the hand, during a gale of wind and rain. The conductor, a vertical cylinder about 10 inches long and 4 inches diameter, with its upper end flat and corner slightly rounded off, stood only 8 feet above the roof, or, in all, 20 feet above the ground, and was nearly surrounded by buildings rising to a higher level. Even with so moderate an exposure as this, sparks were frequently produced between an insulated and an uninsulated piece of metal, which may have been about $\frac{1}{10}$th of an inch apart, within the electrometer, and more than once a continuous line of fire was observed in the instrument during nearly a minute at a time, while rain was falling in torrents outside.

Remarks on the Discharge of a Coiled Electric Cable. *By* Professor W. Thomson, *LL.D., F.R.S.*

Mr. Jenkin had communicated to the author during last February, March, and April a number of experimental results regarding currents through several different electric cables coiled in the factory of Messrs. R. S. Newall and Co., at Birkenhead. Among these results were some in which a key connected with one end of a cable, of which the other end was kept connected with the earth, was removed from a battery by which a current had been kept flowing through the cable and instantly pressed to contact with one end of the coil of a tangent galvanometer, of which the other end was kept connected with the earth. The author remarked that the deflections recorded in these experiments were in the contrary direction to that which the true discharge of the cable would give, and at his request Mr. Jenkin repeated the experiments, watching carefully for indications of reverse currents to those which had been previously noted, It was thus found that the first effect of pressing down the key was to give the galvanometer a deflection in the direction corresponding to the true discharged current, and that this was quickly followed by a reverse deflection generally greater in degree, which latter deflection corresponded to a current in the same direction as that of the original flow through the cable. Professor Thomson explained this second current, or false discharge, as it has since been sometimes called, by attributing it to mutual electro-magnetic induction between different portions of the coil, and anticipated that no such reversal could ever be found in a submerged cable. The effect of this induction is to produce in those parts of the coil first influenced by the motion of the key, a tendency for electricity to flow in the same direction as that of the decreasing current flowing on through the remoter parts of the coil. Thus, after the first violence of the back flow through the key and galvanometer, the remote parts of the cable begin, by their electro-magnetic induction on the near parts, to draw electricity back from the earth through the galvanometer into the cable again, and the current is once more in one and the same direction throughout the cable. The mathematical theory of this action, which is necessarily very complex, is reserved by the author for a more full communication, which he hopes before long to lay before the Royal Society.

On the Necessity for incessant Recording, and for Simultaneous Observations in different Localities, to investigate Atmospheric Electricity. By Professor W. Thomson, *LL.D., F.R.S.*

The necessity for incessantly recording the electric condition of the atmosphere was illustrated by reference to observations recently made by the author in the island of Arran, by which it appeared that even under a cloudless sky, without any sensible wind, the negative electrification of the surface of the earth, always found during serene weather, is constantly varying in degree. He had found it impossible, at any time, to leave the electrometer without losing remarkable features of the phenomenon. Beccaria, Professor of Natural Philosophy in the University of Turin a century ago, used to retire to Garzegna when his vacation commenced, and to make incessant observations on atmospheric electricity, night and day, sleeping in the room with his electrometer in a lofty position, from which he could watch the sky all round, limited by the Alpine range on one side and the great plain of Piedmont on the other. Unless relays of observers can be got to follow his example, and to take advantage of the more accurate instruments supplied by advanced electric science, a self-recording apparatus must be applied to provide the data required for obtaining knowledge in this most interesting field of nature. The author pointed out certain simple and easily-executed modifications of working electrometers, which were on the table before him, to render them self-recording. He also explained a new collecting apparatus for atmospheric electricity, consisting of an insulated vessel of water, discharging its contents in a fine stream from a pointed tube. This stream carries away electricity as long as any exists on its surface, where it breaks into drops. The immediate object of this arrangement is to maintain the whole insulated conductor, including the portion of the electrometer connected with it and the connecting wire, in the condition of no absolute charge; that is to say, with as much positive electricity on one side of a neutral line as of negative on the other. Hence the position of the discharging nozzle must be such, that the point where the stream breaks into drops is in what would be the neutral line of the conductor, if first perfectly discharged under temporary cover, and then exposed in its permanent open position, in which it will become inductively electrified by the aërial electromotive force. If the insulation is maintained in perfection, the dropping will not be called on for any electrical effect, and sudden or slow atmospheric changes will all instantaneously and perfectly induce their corresponding variations in the conductor, and give their appropriate indications to the electrometer. The necessary imperfection of the actual insulation, which tends to bring the neutral line downwards or inwards, or the contrary effects of aërial convection, which, when the insulation is good, generally preponderate, and which in some conditions of the atmosphere, especially during heavy wind and rain, are often very large, are corrected by the tendency of the dropping to maintain the neutral line in the one definite position. The objects to be attained by simultaneous observations in different localities alluded to were,—1. to fix the constant for any observatory, by which its observations are reduced to absolute measure of electromotive force per foot of air; 2. to investigate the distribution of electricity in the air itself (whether on visible clouds or in clear air) by a species of electrical trigonometry, of which the general principles were slightly indicated. A portable electrometer, adapted for balloon and mountain observations, with a burning match, regulated by a spring so as to give a cone of fire in the open air, in a definite position with reference to the instrument, was exhibited. It is easily carried, with or without the aid of a shoulder-strap, and can be used by the observer standing up, and simply holding the entire apparatus in his hands, without a stand or rest of any kind. Its indications distinguish positive from negative, and are reducible to absolute measure on the spot. The author gave the result of a determination which he had made, with the assistance of Mr. Joule, on the Links, a piece of level ground near the sea, beside the city of Aberdeen, about 8 A.M. on the preceding day (September 14), under a cloudless sky, and with a light north-west wind blowing, with the insulating stand of the collecting part of the apparatus buried in the ground, and the electrometer removed to a distance of 5 or 6 yards and connected by a fine wire with the collecting conductor. The height of the match was 3 feet above the ground, and the observer at the electrometer lay on the ground to render the electrical influence of his own body on the match insensible. The result showed a difference of potentials between the earth (negative) and the air (positive) at the match equal to that of 115 elements of Daniel's battery, and, therefore, at that time and place, the aërial electromotive force per foot amounted to that of thirty-eight Daniel's cells.

On the Cause of Magnetism. *By* G. V. Towler.

On Changes of Deviation of the Compass on Board Iron Ships by "heeling," with Experiments on Board the 'City of Baltimore,' 'Aphrodite,' 'Simla,' and 'Slieve Donard.' *By* John T. Towson.

The author explained the manner in which the Compass Committee was first formed, in accordance with the advice of the Section, and stated that two reports had been drawn up, which, with the advice of the Astronomer Royal, had been printed and "presented to both Houses of Parliament by command of Her Majesty." He thanked the Astronomer Royal for his valuable advice and support. There were matters of consideration which the Compass Committee deemed incomplete: the one was the change which took place in iron ships in proceeding to the opposite hemisphere; the other, the change that was produced by what is technically denominated 'heeling,' that is, when the deck of a vessel leaned over, through the action of the wind or otherwise: if, when looking towards the bow, it slanted downwards to the right, it was said to heel starboard; if to the left, to heel port. The first question was undertaken by the late respected Rev. Dr. Scoresby, who proceeded to Australia in the 'Royal Charter,' and whose exertions in the pursuit of this branch of the inquiry shortened a most valuable life. The second question was the subject of his present report. Having described the principles on which his graphic illustration was constructed, the author pointed out the unexpected amount of deviation which this source of disturbance (heeling) brought about, amounting in most instances, when the ship's head was in the position to produce the maximum effect, to two or three points in the standard compass, and to a greater amount so far as the steering compass is concerned. He remarked on several particulars connected with this investigation. Generally the north end of the compass was drawn to the upper side of the ship—the case with seven out of nine compasses on board the 'City of Baltimore;' but in the two steering compasses the needles were drawn in a contrary direction. He explained the theory on which this disturbance arose, partly from subpolar magnetism below the compass, and partly from the disturbance of the inductive magnetism of the ships. In such ships as those under consideration, the following empirical rule held good with respect to compasses favourably placed. When the vertical force, as determined either by vibration experiments or torsion on board the ship, maintained the ratio, as compared with the vertical force on shore, of nine to fourteen, little or no effect was produced by heeling in the same hemisphere and latitude. And in the case of the 'Simla' this plan of predicting the amount of error was adopted: a moveable upright magnet was applied so as to produce the before-named vertical force, when it was found, "with magnet in," no error was produced, although "with magnet out" it amounted to 21° from changing a heel of 10° starboard to 10° port. There appeared to be another remarkable result. He believed that when a ship was built with her head south-east or south-west, little if any effect would be produced by heeling. When examining the magnetic condition of the 'Slieve Donard,' they were surprised to find that the vertical was very nearly that which would give no effect from heeling. Their able stipendiary Secretary (to whom is due the credit of drawing up the two Reports already published) immediately suggested that her head could not have been east when building, which we had taken for granted; and on inquiry we found that, on account of her great length, she had been built diagonally, with her head south-east nearly. Although he believed that for practical purposes sufficient information had been obtained, yet there were anomalies in their observations that rendered the theories deduced unsatisfactory. This he believed arose from the rapidity with which they were obliged to carry on their experiments, on account of the passing in and out of ships through the docks, from which cause the inductive influence of the earth had not sufficient time to complete its effect. It had been proposed to request the aid of the Admiralty in allowing the Committee to experiment on one of Her Majesty's iron ships, in some convenient place, for an unlimited time.

On the Iris seen on the surface of Water. *By* J. J. Walker, *A.M.*

This iris, in shape a more or less obtuse *hyperbola*, may be seen occasionally, in addition to the common rainbow, when a sheet of calm water lies between the spectator and the rain-cloud. It is formed by pencils of variously-tinted rays, which, after emerging from rain-drops, undergo reflexion at the surface of the water; and was first described and mathematically discussed by the author in the Philosophical Magazine for June 1853.

The object of the present communication was to describe the phenomenon by the aid of an illustrative sketch; to point out the relation in which it stood to the secondary *rainbow* observed by Halley, in which the rays had undergone reflexion at the surface of water *before* entering rain-drops; and to suggest the correct mode of delineating it in works of art.

Astronomy.

On the Present State and History of the Question respecting the Acceleration of the Moon's Motion. *By* G. B. Airy, *M.A., D.C.L., F.R.S., Astronomer Royal.*

It had been known, from the time of Newton, that the motions of the moon are disturbed by the attraction of the sun, and that a great part of the effect is of the following kind, viz. that when the moon is between the sun and the earth, the sun attracts the moon away from the earth; and when the earth is between the sun and the moon, the sun attracts the earth away from the moon; and thus, in both cases, it tends to separate the earth and the moon, or diminishes the attraction of the moon to the earth. There are sometimes effects of an opposite character; but, on the whole, the first described is predominant. If this diminution were always the same in amount, the periodic time of the moon passing round the earth would be the same. But it was found in the last century, by Halley and Dunthorne, that the periodic time is not always the same. In order to reconcile the eclipses of the moon recorded by Ptolemy with modern observations of the moon, it was necessary to suppose that in every successive century the moon moves a little quicker than in the preceding century, in a degree which is nearly represented by supposing that at each successive lunation the moon approaches nearer to the earth by *one inch.* The principal cause of this was discovered by Laplace. First, it had been shown by him and by others, that the attractions of the other planets on the sun and on the earth do not alter the longer axis of the orbit which the earth describes round the sun, and do not alter the length of the year; but they diminish slowly but continually through many thousands of years the degree of ellipticity of the earth's orbit. Now, when the earth is nearest to the sun, the decrement of attraction of the moon to the earth (mentioned above) is greatest; and when the earth is furthest from the sun, that decrement is least. It had been supposed that the fluctuations of magnitude exactly balance. But Laplace showed that they do not: he showed that the increased amount of decrement (when the earth is nearest the sun) overbalances the diminished amount (when the earth is furthest from the sun); and, therefore, that the less excentric is the earth's orbit, the less does the increased amount of decrement at one part overbalance the diminished amount at another part, and the less is the total amount of the sun's disturbing force. And, as the sun's disturbing force diminishes the moon's attraction to the earth, that attraction is less and less impaired every century, or becomes practically stronger; every century the moon is pulled into a rather smaller orbit, and revolves in a rather shorter period. On computing the effect from this cause, it was found to agree well with the effect which Halley and Dunthorne had discovered in observations. The lunar tables thus amended (and with other, but minor improvements) were applied to the computation of other ancient eclipses which require far greater nicety than Ptolemy's lunar eclipses, namely, total eclipses of the sun. The most remarkable of these were the eclipse of Thales (which occurred at a battle), that at Larissa or Nimrúd (which led to the capture of that city by the Persians from the Medes), and that of Agathocles (upon a fleet at sea). They are all of great importance in settling the chronology. Dates were thus found for these several eclipses, which are most satisfactory. About this time Mr. Adams announced his discovery, that a part of the sun's disturbing force had been omitted by Laplace. The sun pulls the moon in the direction in which she is going (so as to accelerate her) in some parts of her orbit, and in the opposite direction (so as to retard her) in other parts. Laplace and others supposed that those accelerations and retardations exactly balance. Mr. Adams gave reason for supposing that they do not balance. In this he was subsequently supported by M. Delaunay, a very eminent French mathematician, who, making his calculations in a different way, arrived at the very same figures. But he is opposed by Baron Plana, by the Count de Pontécoulant, and by Prof. Hansen, who all maintain that Laplace's investigations are sensibly correct. And in this state the controversy stands at present*. It is to be remarked, that observations can here give no assistance. The question is purely whether certain algebraical investigations are right or wrong. And it shows that what is commonly called "mathematical evidence" is not so certain as many persons imagine; and that it ultimately depends on moral evidence. The effect of Mr. Adams's alteration is to diminish Laplace's change of the periodic time by more than one-third part. The computations of the ancient eclipses are very sensibly affected by this. At present we can hardly say how much they are affected: possibly those of Larissa and Agathocles would not be very much disturbed; but it seems possible that the computed eclipse of Thales might be thrown so near to sunset as to be inapplicable to elucidation of the historic account. This is the most perplexing eclipse, because it does not appear that any other eclipse can possibly apply to the same history. The interest of this subject, it thus appears, is not confined to technical astronomy, but extends to other matters of very wide range. And the general question of the theory of the moon's acceleration may properly be indicated as the most important of the subjects of scientific controversy at the present time.

On the Mid-day Illumination of the Lunar Craters Geminus, Burckhardt, and Bernoulli. By W. R. Birt, *F.R.A.S.*

The object of the present communication is to lay before the British Association for the Advancement of Science a few of the features that characterize the lunar surface in the neighbourhood of the craters, Burckhardt, Bernoulli, and Geminus, or more particularly on the area between the angular points: Burckhardt, Bernoulli, a small but bright crater on the southern margin of Messala (B), and a crater on an elevated ridge (a*) *under the mid-day illumination.*

In the first report of the Committee appointed at Belfast to report on the physical character of the moon's surface, the mid-day illumination is alluded to as "making apparent the unequal reflective powers and different colours which characterize the different lunar regions, and the systems of brilliant stripes which are connected with certain lunar forms."

* See also Mr. Main's elaborate statement in the Monthly Notices of the Royal Astronomical Society.

The drawing accompanying this communication exhibits such reflective powers and different shades of tint, as well as certain remarkable phenomena connected therewith, which appear to be entirely unconnected with hypsometric relations, and manifest only the *ground markings* of this part of the lunar surface. It (the drawing) has resulted from the personal observations of the author, in accordance with the recommendations of the above-named Committee, and is perfectly unconnected with any *previous* delineations of this part of the moon's surface, further than the relative positions of the three principal craters, which have been taken from Beer and Madler's large map, the observations having been made with one of the Sheepshank's telescopes, the property of the Royal Astronomical Society, each consisting of an original sketch executed at the time of observation. They extend from April to July of the present year. The features delineated may be seen during the period of the lunation that elapses between ten and fourteen days of the moon's age.

In the following description each feature will be separately noticed, preceded by a Roman numeral. References :—Names and Roman characters to Beer and Madler's map, Arabic numerals to features that appear to be new to the author, or, in other words, that *he* has not met with a description of.

I. *Burckhardt.*—The appearance usually presented by this crater under this illumination is that of an ellipse, the northern and southern margins being more strongly illuminated than the eastern or western, which evidently results from the incidence of the solar light. The crater is in reality (as determined from hypsometrical inequalities brought out by morning and evening shadows) one that is superposed on an older depression, the extremities of the older crater being well marked in the evening illumination. No part of the ancient one is seen between ten and fourteen days of the moon's age, only the brighter rim of the modern, with a central mark somewhat more luminous than the floor.

II. (*c*) A somewhat intensely bright circular spot near the south-western margin of Geminus. It is a small crater very apparent in the morning illumination, but almost disappearing under the evening.

III. (1) A dark mark near (*c*). It is not in the nature of a shadow, the incident light being opposed to that view. The author is disposed to regard it as a portion of the surface reflecting much less light than the crater.

IV. (2) A bright narrow stripe emanating from (*c*) directed towards Burckhardt: this stripe may be slightly too wide in the drawing.

Note.—There is an extremely brilliant crater in Cleomedes (A) in Beer and Madler's map, with a similar stripe towards Burckhardt.

V. (3) A bright stripe from (2) towards the dark ribbon (15) : this stripe extends considerably beyond the dark ribbon towards the east.

VI. (4) An extensive space of nearly the same uniform tint; it is rather darker between Burckhardt and Bernoulli, and covers *the southern part* of GEMINUS.

VII. *Bernoulli.*—The floor of this crater under the mid-day illumination is *dark*, with a light rim seen under the same circumstances as the rim of Burckhardt.

VIII. (a) A small but well-marked crater between Bernoulli and Messala.

IX. (5) A curved bright stripe somewhat hooked, extending from (a) to Bernoulli.

X. (6) A dark space somewhat lighter than the floor of Bernoulli, extending between Bernoulli and Messala. It is not of the form shown in the drawing, a small portion extending further west.

XI. (B) A crater on the margin of Messala; it is not distinctly discernible under this illumination.

XII. (7) A *bright* space *covering the northern part* of GEMINUS, extending and *converging* to (B), the crater in the southern margin of Messala.

XIII. (8) A bright narrow stripe *crossing* GEMINUS; it passes through the dark ribbon, as may be seen with a powerful instrument, and extends towards the north of Cleomedes across the narrow stripe (3).

XIV. (9) A bright narrow curved stripe, apparently the north-western margin of GEMINUS. It is seen eastward of the dark ribbon, and extends towards the eastern extremity of the stripe (3).

XV. (10) A dark space somewhat like a spur, apparently *within* and *external* to GEMINUS, and dividing the curved stripe on its margin.

XVI. (a*) A small crater which is situated *upon* the northern extremity of a *ridge* (not the ribbon 15), as manifested by the morning and evening illuminations. This ridge does not exhibit any reflective powers *different* from those of the surrounding land.

XVII. (11) The outlines of an *obliterated* crater with its *darker* floor and somewhat *lighter* rim than the space (12). No indications of any hypsometrical relations of this crater are met with morning and evening, so that it would appear to have been *filled* up. It is a somewhat difficult object to see, and requires good definition.

XVIII. (12) A space of nearly the same uniformity of tint as (4) between Geminus (a*) and (B). It is rather darker towards the ribbon.

XIX. (13)
XX. (14) } Two small somewhat light spots; they do not appear to be craters.

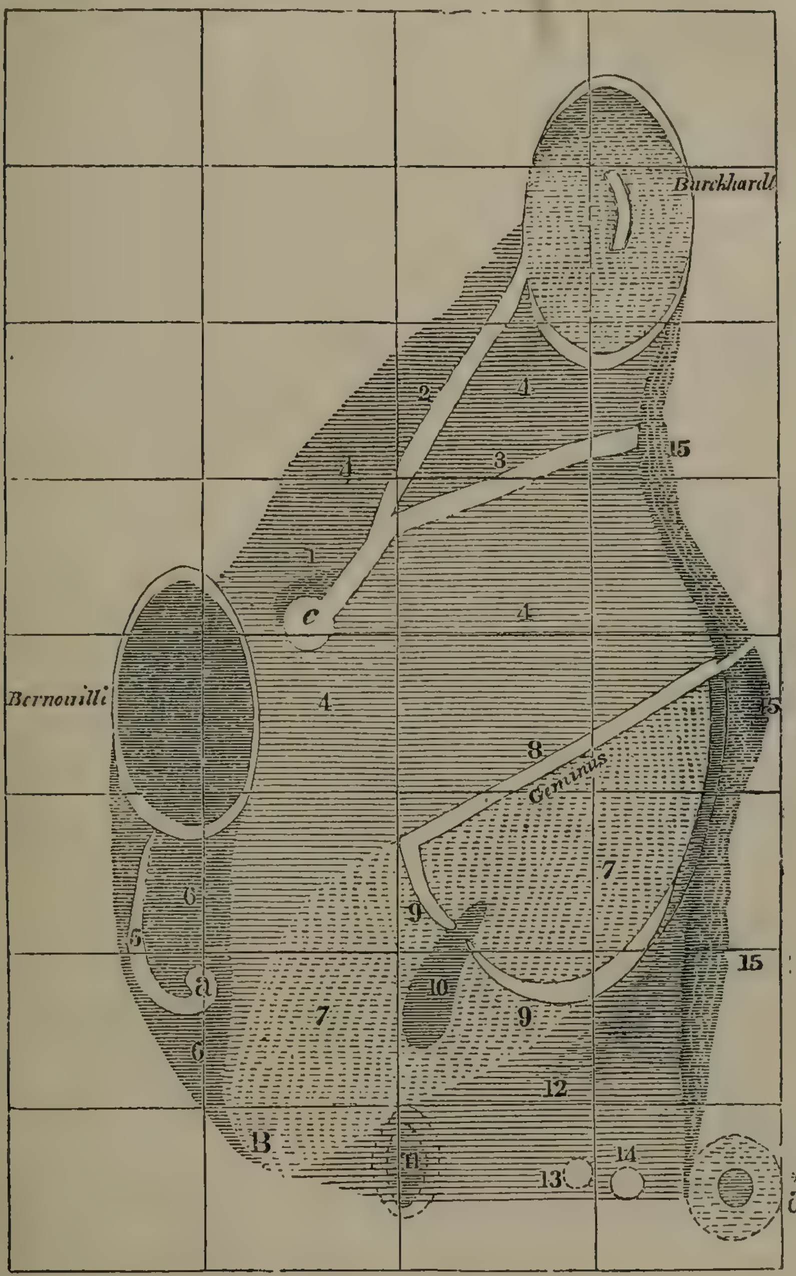
XXI. (15) A dark ribbon-like band extending from *Burckhardt* to *Geminus*, skirting the eastern margin of *Geminus* and proceeding towards (a*).

This dark ribbon is not in any way *elevated* above the general lunar surface, as *no shadow* is perceptible either in the morning or evening; in fact it disappears entirely under these illuminations. It is clearly a "*ground mark*" exhibiting differing degrees of intensity.

Contemplating the drawing as it lies before us, we see at a glance that during the four days (moon's age 10 to 14) we are dealing *in this part of the moon* with markings of the surface only. This conclusion is particularly forced upon us by the remarkable phenomena presented by GEMINUS. The depth of this crater, as well as the elevation of its walls, are well brought out by light and shadow, especially in the forenoon illumination, but as the day advances the crater-form is lost; in fact such is the metamorphosis the crater *undergoes*, that only a portion (the northern) is recognizable, and this more by the curved outline and narrow stripe across, than by anything else. Between the dark ribbon (15) and the dark space north of Bernoulli (6), including the dark-floored Bernoulli itself, a space of somewhat uniform breadth extends. This space, which is of a lighter tint than either of the narrower stripes bounding it east and west, is crossed by a *brighter* space (7), which passing over *Geminus*, converges to the crater (B) in the southern margin of Messala. This brighter space is *not peculiar* to the locality between the two narrow darker fringes; it extends considerably to the eastward of Geminus, passes near to a crater marked by Beer and Madler (A), and is connected with the system of brilliant stripes radiating from the brilliant crater Proclus. The narrow stripe (8), which is rather brighter, belongs to the same class as (2), (3), and (9), and may be seen crossing *Geminus* on the eighth day of the moon's age, both northern and southern walls being apparent; it consequently traverses alike elevation and hollow. It would appear (assuming for a moment that the bright space (7) existed anterior to the production of the crater, an assumption by the by for which there are no reasonable grounds) that that production had not in the least degree influenced the reflective powers of those parts of the surface on which the crater is situated. On the other hand, assuming that both brighter and darker tints resulted from some *change* after the crater was produced, it is difficult to see how the *complete obliteration* of the southern part should be effected at the same time that its elevated wall remains. That the wall is not materially interfered with, is evident from the fact that both wall and depression come out in strong relief with the evening shadows.

It is very possible that the crater might have been produced *when* the entire area between the two dark fringes reflected light *similarly*, and that its southern wall with its step or terrace only presented phenomena of light and shade when the morning and evening incidences were such as to bring them out from hypsometrical inequality. The narrow stripe (8) across is evidently posterior in age to the crater itself, and may or may not be contemporaneous with the production of the lighter area converging to Messala; and from the distinct and well-marked manner in which the north-western rim is *cut off* at the junction of the lighter and darker areas, it would appear that this brighter rim is also of later origin.

The bright crater (C) deserves a passing remark. On consulting Beer and Madler's map, it will be seen that Burckhardt is situated nearly midway between it and the bright crater marked (A) in Cleomedes, from which a similar stripe extends to Burckhardt. A question here suggests itself. Is Burckhardt at a *lower level* than either (C) or (A)? The author has not yet detected hypsometrical evidence of this: or has there been some tendency in the direction of Burckhardt to produce cracks and fissures *from* the two small craters N.W. and S.E. of it?



Epoch ten to fourteen days of the moon's age.

Mid-day illumination of the lunar area between the angular points Burckhardt, Bernoulli; B a crater on the southern margin of Messala and the crater a*.

Relative positions, *approximately*, from Beer and Madler's large map.

Names and Roman characters refer to Beer and Madler's large map.

Arabic numerals to features observed by the author, described in the accompanying paper, and not described elsewhere, so far as the author is aware.

Drawn from sketches taken at intervals between April and July 1859.

On Sir Christopher Wren's *Cipher, containing Three Methods of finding the Longitude. By* Sir DAVID BREWSTER, *K.H., LL.D., F.R.S.*

Sir David said that at page 263, vol. ii. of his 'Life of Sir Isaac Newton,' the following paragraphs would be found:—" The bill which had been enacted for rewarding the discovery of the longitude seems to have stimulated the inventive powers of Sir Christopher Wren, then in his eighty-third year. He communicated the results of his study to the Royal Society, as indicated by the following curious document which I found among the manuscripts of Newton :—

" 'Sir Christopher Wren's cipher, describing three instruments proper for discovering the longitude at sea, delivered to the Society November 30, 1714, by Mr. Wren :—

OZVCVAYINIXDNCVOCWEDCNMALNABECIRTEWNGRAMHHCCAW.
ZEIYEINOIEBIVTXESCIOCPSDEDMNANHSEFPRPIWHDRAEHHXCIF.
EZKAVEBIMOXRFCSLCEEDHWMGNNIVEOMREWWERRCSHEPCIP.

Vera copia. EDM. HALLEY.'

We presume that each of these paragraphs of letters is the description of a separate instrument. If it be true that every cipher can be deciphered, these mysterious paragraphs, which their author did not live to expound, may disclose something interesting to science."

Sir David Brewster went on to say that soon after the publication of 'The Life of Sir Isaac Newton,' he had received a letter from Mr. Francis Williams, of Grange Court, Chigwell, suggesting very modestly that as the deciphering of the cipher, as published, was so simple, he supposed many persons had already done so; but if not, he begged to say that the mystery could be solved by reading the letters backwards in each of the three paragraphs, omitting every third letter. He had, on the approach of the Meeting of the British Association, received permission from Mr. Williams to give an account to this Section of Mr. Williams's method of solving the enigma. In his letter conveying the permission, which Sir David read, he suggests that " Sir Christopher Wren's object was to make it too mysterious to be of use to any one else. It is possible he may have wished to delay for a time the publication of his inventions, perhaps till he had improved his instruments, but was afraid that in the interval another would hit upon and publish the same discovery. He would send this cipher, then, to the Royal Society as a proof to be used at any future time." Sir David had the following explanation then, in accordance with Mr. Williams's suggestion, written upon the black board, the letters to be omitted being written in small characters to distinguish them, and backwards :—

WAcCHhMArGNwETrICeBAnLAmNCdEWcOUcNDxINiVAvCUzO.—Wach magnetic balance wound in vacuo (one letter a misprint). The omitted letters similarly read are—CHR. WREN, MDCCXIV.

FIcXHhEArDHwIPrPEeSHnANmDEdSPcOIcSExTUiBEiONiEYiEZ.—Fix head hippes handes poise tube on eye (one letter a misprint). Omitted letters make—CHR. WREN, MDCCXIIII.

PIcPEhSCrREwWErMOeVInNGmWHdEEcLScFRxOMiBEvAKzE.—Pipe screwe moving wheels from beake. Omitted letters make—CHR. WREN, MDCCXIV.

The three last omitted z's occurring in the first part of each cipher to show that that part must be taken *last*.

On the Longitude. By Sir C. GREY.

On the Inclination of the Planetary Orbits. By J. POPE HENNESSY, *M.P., F.G.S.*

The author stated that, on consulting a synoptic table of the planetary elements, some laws had been obtained for the other elements, but none hitherto for the inclinations of the several orbits. This he conceived arose from the inclinations being set down in reference to the plane of the earth's orbit; for he found that a very remarkable relation manifested itself when they were tabulated in reference to the plane of the Sun's equator. The author had written on the board two tables: one, the ordinary table, in reference to the Ecliptic; the other, that to which he wished to draw attention, having reference to the plane of the Sun's equator. In the latter it was seen, as a general law, that the inclinations of the planetary orbits increased as the distances of the several planets from the sun increased. Thus, the inclination of the orbit of Mercury to the plane of the Sun's equator was but 0° 19′ 51″, while that of Neptune was 9° 6′ 51″,—the only considerable deviation from regular progression being found, as might be expected, among the asteroids; of which if we take Victoria as a type, her inclination is no less than 15° 42′ 15″. The author considered that the fact that the orbits of the larger planets, Jupiter, Saturn, Uranus, and Neptune, are not more inclined, would seem to confirm a surmise of La Place, who, in his 'Exposition du Système du Monde,' speculates on the order in which the planets were thrown off from the Sun, and supposes that Jupiter, Saturn, &c. were thus formed long before Mercury, Venus, the Earth, and Mars. If so, the oblateness of the Sun would, in its condition at that time, have tended more powerfully than in its subsequent or present state to keep the planets near the plane of its equator. The discovery of this law regulating the inclinations of the planetary orbits appeared to him another addition to the class of facts which establish the analogy between the Solar system and that of Jupiter and his satellites, it being well known to astronomers that the inclination of the orbits of the latter to the plane of Jupiter's equator was a function of their distances and masses.

On Chinese Astronomy. *By* J. B. Lindsay.

The object of the present paper is to draw the attention of this Section to the fact, that much information may be derived from Chinese literature in order to perfect our astronomy. The 'Chun-tsiu,' written by Confucius, contains an account of thirty-six eclipses (several of them total), and several comets, falling stars, and meteorites. The first eclipse here recorded was in the year before our era 719, the last was in B.C. 494, thus comprising 225 years. Confucius was born in B.C. 550, and died at the age of seventy-three in B.C. 477. In a book lately published I have given an extract of the thirty-six eclipses; but the whole of the 'Chun-tsiu' deserves to be translated and published. I have myself made a translation of the whole *verbatim*, but should prefer seeing it published by another better acquainted with the Chinese. The 'Chun-tsiu' is a short chronicle of events; but there is an extended commentary on it entitled the 'Tso-chuen,' by Tso-kiu-ming, who was a contemporary and an intimate friend of Confucius. This work should, I think, be also translated, as it gives a detailed account of astronomical observations, and comes thirteen years further down than the work of Confucius. Another work, entitled the 'Kwo-yu,' supposed to have been by the same author, contains an Appendix by another person, bringing down the history to B.C. 453. The succeeding history was principally written, and the celestial phenomena recorded, by Szi-ma-tsien, who lived a century before our era. His work is entitled 'Shi-ki,' or Historic Memoirs. He was Imperial Historian, as was also his father; and his work is extremely interesting, as giving an account not only of Chinese affairs, but also of the Scythians and Turks who were then on the north-west borders of China. The 123rd chapter, recording foreign events, has been translated into French by Brosset, and is found in the Journal Asiatique for 1828. This chapter comprises the history of forty-three years, or from B.C. 140 to B.C. 97, shortly before the author's death. Small portions of the 'Shi-ki' have been translated into English, but the whole deserves to be so. A translation of the whole Chinese history and literature before our era would not be voluminous; but the 'Chun-tsiu,' the 'Tso-chuen,' and the 'Shi-ki' should, I think, be translated first. Extended notes would be necessary to render the whole intelligible, and the Astronomer Royal might append notes on the various eclipses. The ancient Chinese classics are nine in number,—five of the first class, and four of the second. The five of the first class are the 'Shu-king,' the 'Shi-king,' the 'I-king,' the 'Li-ki,' and the 'Chun-tsiu.' The 'Shu-king' has been translated into French by Desguignes,; the 'Shi-king' into Latin by Lacharme; the 'I-king' into Latin by Regis, and others; the 'Li-ki' into French by Callery; but the 'Chun-tsiu' has not yet been translated into any European language. The four books of the second class have been often translated into Latin and French. Their names are, the 'Ta-hio,' the 'Chung-yung,' the 'Lun-yu,' and 'Mang-tszi,' or Mencius,—scarcely any of which have been translated into English.

On an Improvement in the Heliometer. *By* NORMAN POGSON, *Director of the Hartwell Observatory.*

The purpose of this communication is to suggest what I conceive to be a great addition to the power of any kind of micrometer used for measuring long distances on the double-image principle. It is therefore especially applicable to heliometers, and has indeed occurred to me chiefly from familiarity with the defects which have hitherto rendered this costly but magnificent instrument a comparative failure. It is well known to practical astronomers that the contact between two stars, however skilfully made, is a very unsatisfactory observation, even when the objects are pretty equal. But when one is a large bright star and the other a faint one, the difficulty and uncertainty amount to impossibility; for the faint star is invariably obliterated on approaching within two or three seconds of its superior. The alternative is then to diminish the aperture of that half of the object-glass through which the brighter star is viewed; but here again arises another evil; the disc is enlarged by diffraction, the value of the scale sensibly changed, and definition materially injured. Hence parallax determinations of first magnitude stars, such as Arcturus and *a* Lyræ, cannot be satisfactorily made; but when the object is a double star, as, for instance, 61 Cygni or Castor, the comparison star can be brought *between* the components of the double star, and a most exquisitely perfect and comfortable measure obtained. Now, from having used the rock-crystal prism micrometer when residing at Oxford last year,—then kindly lent me, together with a five-foot telescope of surpassing excellence, by Dr. Lee,—the idea occurred to me of introducing a prism, or achromatized wedge of rock-crystal, into the heliometer, so as to double the image of the brighter star. By this means the dubious contact would be dispensed with; for the fainter object, by being brought midway between the two images of the bright star, would be precisely similar to the present easy observation of 61 Cygni previously referred to. The prism could be of such a constant angle as to separate the two images to a convenient distance; not too far, so as to render the estimation of distance difficult, but just wide enough to prevent the obliteration of a faint comparison star, before named as one of the evils to be avoided. The prism rather improves the appearance of a bright star than otherwise; and as the images are doubled, of course half the light of each is lost, equivalent to a considerable reduction of the aperture, thus obviating the third objection alluded to at starting. Armed with this addition to its strength, and taking the precaution never to observe on bad nights, when the atmosphere will not permit the use of powers from three hundred upwards—for I hold it as an absurdity to attempt to investigate tenths of a second of arc with anything less—the heliometer is doubtless yet destined to realize the highest expectations ever raised, as to its efficiency for grappling with that most minutely intricate and vastly important research, viz. the parallax of the fixed stars!

On three Variable Stars, R and S Ursæ Majoris, and U Geminorum, as observed consecutively for six years.* *By* NORMAN POGSON, *Director of the Hartwell Observatory.* (*Communicated by* DR. LEE.)

[With a Plate.]

The periodical variation in brilliancy of certain fixed stars has now been known to astronomers for more than two centuries. The fact of simple change, apart from periodicity, has been recognized and recorded for nearly two thousand years; and while every other celestial phenomenon has been explained and reduced to intelligible methods of calculation, based upon theories as incontrovertible as the events they foretell in future or account for in past times, these changes of light and colour remain enshrouded in mystery, and their prediction as purely empirical as was that of eclipses by the Chaldeans of old, aided by their renowned Saros, or eclipse-period of 223 lunations.

It is not, however, for want of due thought and attention from the eminent astronomers of the past and present that such a reproach attaches to any branch of their science. Commencing with Fabricius, who first drew attention to the dis-

* This paper was illustrated by large diagrams of the light curves of the above three variable stars, covering an area of more than sixty square feet. The portions most especially referred to by the author have been reduced to a suitable scale, and are given in Plate I.

appearance of the now well-known variable Mira Ceti, and the Dutch Professor Holwarda, who discovered its periodicity, the list of observers of these objects includes most of the greatest names that have figured in astronomy:—Hevelius, Bulliald, Montanari, Cassini, Maraldi, G. and C. Kirch, Halley, Koch, Goodricke, and Pigott—all contributed largely by discovery or observation to our knowledge of the variable stars. Sir William Herschel's first astronomical communications were upon the same subject, since most ably followed up by Sir John Herschel, the distinguished inheritor of his great name and lofty talents. Olbers paid great attention to the variable stars, as also Harding, Wurm, Westphal, Schwerd, and above all others, Professor Argelander, of Bonn. To him is due not merely the merit of arranging the labours of all that had preceded him, and more accurately investigating the elements of change of most of the old variables, as well as the discovery of several new ones, but that of training a band of young and able followers, who by their successive discoveries and patient researches have honoured both themselves and their great instructor. In England, besides the labours of Sir John Herschel, Mr. Hind has discovered no less than twenty-one new telescopic variable stars, two of which, S Cancri and U Geminorum, are especially remarkable. The writer of this paper has also contributed ten to the list, which now numbers more than eighty of these interesting objects. Mr. Baxendell of Manchester, Messrs Chacornac and Goldschmidt of Paris, as well as Drs. Winnecke, Schœnfeld, Luther, Auvers, Hoek, Oudemans, and Schmidt, are all devoting more or less of their time and attention to the same pursuit.

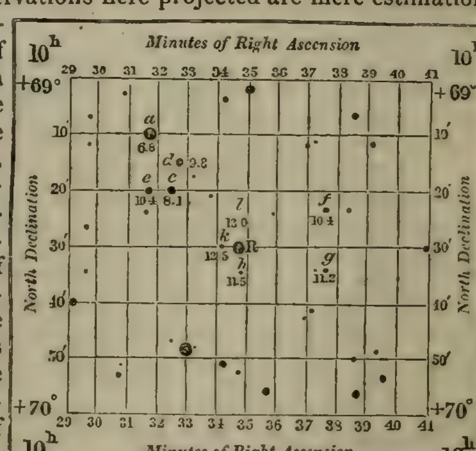
Why then, it may be inquired, have not all these combined efforts proved as successful as they undoubtedly deserved to be, in arriving at more satisfactory results? We can only regret the circumstance, and redouble our exertions to attain so important an object. Want of continuity is doubtless a most weighty objection to all previously published series of observations, and one which the observers could not help: for unless a star be circumpolar, there must inevitably occur a break in the records of its changes during the time that it is in conjunction with the sun, and therefore not observable. It is not enough merely to watch a star through its successive maxima; every stage of its variation should be remarked, and an unbroken record thereof kept for years, or at least through ten or twelve complete periods. The detection of four remarkably regular variable stars, suitably placed in the circumpolar region, has enabled me to secure this desideratum, and to supply data not previously available.

A brief summary of the principal features hitherto remarked in periodical stars, may be advantageously stated, before proceeding to the description of our illustrations. Some of them, from fine bright stars distinctly visible to the naked eye, fade away beyond the limits of the largest telescopes in use, and after remaining invisible a certain time suddenly regain their brilliancy. The increase in light is generally more rapid than the diminution, and about or after maximum such stars are frequently more or less red. Others, usually of short period and small variation, complete their changes in a few hours, and at all intermediate stages are of a constant magnitude. Most of the stars of this class are visible to the naked eye and pretty steady in their periods, which may be stated as between the limits, three and forty-six days; while those of the former class, or vanishing stars, range from 97 to 650 days in the interval between two successive maxima. In one instance the period cannot be less than seventy-three years; and it is even probable that some of the brilliant visitors, described as new or temporary stars in past ages, may be periodical, but returning only after the lapse of many centuries.

The largest of our three diagrams represents the light curve, or graphic history, of the circumpolar variable star R Ursæ Majoris, since 1853, the year of discovery of its variability. Eight maxima, dependent upon 138 observations, and seven minima, resting upon 122 observations, making in all 260 nights on which the star has been examined, are here presented to the view. The Time co-ordinates, marked along the top and bottom of the projection, are on a scale of ten days to an inch. The other co-ordinate—magnitude or light—is marked at each extremity of the diagram. The upper limit, which, however, this star has never attained, is the 6th magnitude, or faintest visible to the unassisted sight. The lower limit is 13½, or the faintest magnitude discernible with a telescope of 7 inches in aperture. The observation of every night is represented by a black spot. Thus, on 1855, September 19, the magnitude of the star was recorded 6·6; on November 8, it had diminished to 8·8; and on 1856, March 7, when only just discernible, it was noted 13·5. It appears therefore, that if R Ursæ Majoris never becomes visible to the naked eye, on the other hand it never quite vanishes with an object-glass of 7 inches in aperture. A waved line, smoothly traced among these dots, so as to pass as nearly as possible through the mean of each three successive observations, is adopted as the curve which represents the variations of the star with the most probable exactitude. The general regularity and similarity of the different periods is strikingly evident, also the gradual descent of the curve corresponding to diminution of light, and its rapid ascent or brightening up before each maximum. The whole period being 302 days or ten months, the interval from maximum to minimum is 191 days, that from minimum to maximum only 111 days.

Closer inspection will bring to view some more interesting details. At the first observed maximum the star acquired only the 8th magnitude. At the next it became 0·6 of a magnitude brighter, or shone with half as much light again as on the first occasion. On the photometric scale adopted, which is an average of those employed by all the chief catalogue constructors who paid attention to the relative magnitudes of the fixed stars, and is in exact accordance with the notation of Professor Argelander, the highest authority on that point, one star is said to be a magnitude brighter than another, when it contains 2½ times the actual light of the fainter star. Thus a 7th magnitude is 2½ times as bright as an 8th. At the next three maxima, viz. 1854, November 22; 1855, September 15; and 1856, July 10, R Ursæ Majoris was within 0·1 of the 7th magnitude. But at the next maximum on 1857, May 15, it reached the 6·7 magnitude—the brightest on record; a veritable maximum maximorum! On the last two occasions, viz. 1858, March 16, and 1859, January 5, it did not exceed the 7·6 magnitude. Owing to the extreme faintness of this star at its minima, less weight can be assigned to their determination, but similar fluctuations are manifested, especially by the first four. After reducing the fifteen equations afforded by this curve, by the method of least squares, the resulting elements of variation are:—period, 301·91 days; epoch of minimum, 1858, September, 15·9; and that of maximum, 1859, January, 6·6; which represent the original observations with surprising accordance. The mean difference between an observed maximum and one computed from the elements is 2¾ days; the extreme difference 5¼ days. For the minima, these differences are—mean, 4½; extreme, 8 days. Strong evidence this, in favour of the regular periodicity of the star, and the sufficiency, both of the observations and their treatment by this simple but effectual method of projection, when for two of the oldest known variables, *o* Ceti and χ Cygni, the most refined formulæ of calculation often disagree with observation to the extent of twenty-five and forty days respectively!

It must not be supposed that the observations here projected are mere estimations of the magnitude of the variable; neither are they photometric measures of the actual light emitted by the star. In either case, the changes in the atmosphere or in the sensibility of the observer's eye would materially affect the estimation, and the dots would stand out very unsatisfactorily from the interpolating light-curve. The method employed is as follows:—A map of the neighbourhood of each variable is constructed, and a certain number of stars selected, if possible in the same telescopic field of view, as standards of reference. One of these maps, viz. that of the variable just described, is here given for the purpose of illustration.



The comparison stars, nine in number, are lettered in order of brilliancy, and their adopted magnitudes, the means of careful estimations on twenty favourable nights, are as marked on the map. The variable star is compared with these selected standards on each occasion. Thus, on 1855, December 18, my record made with the equatorial of the Radcliffe Observatory was—*R*, 0·8 of a magnitude less than comparison star *d*; 0·3 less than *e*; equal to *f*; 0·6 brighter than *g*; which differences, applied to the adopted magnitudes of the references employed, yield the four values 10·6, 10·7, 10·4, 10·6. The mean of these, 10·6, is then the relative magnitude of R Ursæ Majoris on that night, eliminating all the liabilities to error which could attend direct estimation. The eye is wonderfully acute, after a little practice, in detecting differences of brilliancy, second only to the ear in distinguishing small intervals of musical sound; and an inequality between two stars of only $\frac{1}{30}$th of their light, considerably less than a tenth of a magnitude, is fairly appreciable.

Three maxima, forming a portion of the light-curve of S Ursæ Majoris, another of the four circumpolar variables found at the Radcliffe Observatory, are projected in a precisely similar manner, and on the same scale as in the preceding example. The period and range of variation of this star are each considerably less than in the case of R Ursæ Majoris. Its changes are completed in 222½ days or about 7½ months. The brilliancy at different maxima fluctuates between the 7·5 and 8·5 magnitudes. The minima also lie between the 11·8 and 12·8 magnitudes. The times of increase and decrease are performed in 95 and 127 days respectively. The most singular feature exhibited by this star, is the different duration of greatest brightness at certain maxima. For instance, at the very flat-looking maximum which occurred on 1855, June 17, S Ursæ Majoris preserved the same intensity, viz. the 8·4 magnitude, for nearly two months. At the next maximum, 1856, February 11, the star acquired the 8·2 magnitude, but changed more in twenty days than previously in nearly three times that interval. At the next return, 1856, September 14, it increased to the 7·7 magnitude, but scarcely remained a fortnight at greatest brilliancy. The minimum also, on 1855, October 24, when of the 12·3 magnitude, compared with the next on 1856, January 14, is much sharper and shorter, as well as fainter in its actual light. Since May 1853, when its variability was first detected, the star has been examined on 270 nights, comprising eleven minima and ten maxima in unbroken succession.

On looking at such a long flat vertex to a curve, as the first on the diagram of S Ursæ Majoris, it may be asked how the exact day of maximum is deduced, when the star remained so little changed for two months? The small circular marks and the short line traced through them are the reply to this inquiry. Reading from the light curve the days on which the star was of equal brightness during increase and decrease, a mark is placed half-way, or at the mean of the two days. This is done for different stages of brightness,—in this instance when the star was of the 10·2, 9·8, 9·4, 9·0, and 8·6 magnitudes. A curve is then smoothly passed through these points, and the point defined by the intersection of the light-curve with this line is regarded as the day of maximum intensity. Any more refined process would be but labour lost. Projection has two great advantages over calculation, when applied to these observations; it economizes time, and by the flagrant outstanding of any particular dot, immediately detects errors which might easily escape notice when intermingled in a column of figures, but which would not fail to vitiate our results if overlooked, in the deduction of the elements of variation.

R Cygni, a star of 417 days period—discovered in August 1852, and since then continuously examined on 243 nights—is a third circumpolar variable, extremely steady in its changes. It descends from the 8th to below the 14th magnitude in 245 days, but returns to its next maximum in 168 days. It is quite invisible with a 7-inch object-glass for above three months.

The fourth circumpolar variable, R Cassiopeiæ, likewise increases rapidly, fading away very gradually; the whole period extending over 435 days or more than 14 months, and ranging generally from the 6th to the 13th magnitude. At maximum this star emits a vivid red or almost a scarlet light. R Cygni and S Ursæ Majoris also show a fine deep red tinge. R Ursæ Majoris, on the contrary, never appears red, nor indeed deviates from its ordinary yellowish-white colour at any part of its period.

In striking contrast to these, and indeed to most other variables, stands U Geminorum—a truly wonderful star, discovered by Mr. Hind in December 1855. Its short period of 97 days was detected at the Radcliffe Observatory, at its very next return, in March 1856. The star is visible only for about ten or twelve days. To what an infinity of faintness it must diminish during its 85 days of invisibility is beyond all conception, and perfectly overwhelming to the imagination! Its appearances show a pretty regular periodicity; but here again it is strangely anomalous, for it sometimes fails to return at all, as will shortly appear from the projection. The colour is invariably bluish white, and at some maxima its light is ever dancing and unsteady; at others exactly the reverse, as pale and calm as a planet's. Requesting attention to the diagram so freely striped with red* lines, the upper limit no longer represents the 6th but the 7·5 magnitude; the lowest line, the 15th—a trifle beyond the vanishing-point of the large reflector of Mr. Worthington, of Manchester; which has been directed to it frequently, and to excellent purpose, by my friend Mr. Baxendell, of that city.

At its discovery by Mr. Hind, on 1855, December 15, it was estimated of the 9th magnitude, and was announced in the *Times* as "a new planet at its stationary point, or a new variable star." On December 18 it was a little fainter, though still visible, but disappeared before the end of the month. The black hyperbolic-looking curve, shaped agreeably to later re-appearances, but fitted in to Mr. Hind's dates, shows the probable nature of its changes at its first recognition. The red lines following are records of invisibility, showing that the star was looked for but not seen, and therefore less than the magnitude indicated by the top of each such red line. Thus, on 1858, May 16, an unfavourable night at Manchester, stars of the 13·4 magnitude were just visible when U Geminorum was not. On 1856, January 12, a fine night, it was invisible to Mr. Hind with the South Villa equatorial, and therefore less than 13·5 magnitude. On January 27, when sought for at Oxford, with a small but excellent portable telescope, $2\frac{1}{4}$ inches in aperture, it was invisible, and under the 11th magnitude. As previously stated, its period was detected at its first return, at the Radcliffe Observatory, when three observations were obtained. It must have passed its maximum on 1856, March 23. It was seen of the 9·6 magnitude on the 26th; of the 10·2 magnitude on the 27th; of the 11th magnitude on the 29th, but had quite disappeared on April 2, and was then less than the 13·5 magnitude. Several records of invisibility follow up to the middle of June, when the star not being circumpolar was lost sight of at its conjunction with the sun. From May till September it is not observable from this cause. The maxima due on June 25 and September 30 were thus lost. The next, on 1857, January 5, was also lost, owing to the prevalence of cloudy weather from December 29 to January 14. The records of invisibility are, however, pretty numerous about this time, and prove it was well looked after. The maximum of 1857, April 9, was well observed, the star being seen *twice* before, and *five* times after the turning-point by me; and *once* on April 13, as a 10·3 magnitude, by Mr. Baxendell, on a night when I had no observation. It is gratifying to find the independent comparisons of two observers —different eyes and telescopes—thus perfectly agreeing with the same unbroken light curve. U Geminorum was again lost in the summer months at its conjunction, and therefore the maximum due on July 18 escaped observation. On October 30 the variable was *visible*, but only of the 9·7 magnitude, and as it was invisible and under the 12·3 magnitude on October 27, when already five days past due, it is probable that it did not surpass the observed magnitude at that maximum.

An important stage of its history is now at hand. It was being sought for at Oxford, and also at Manchester, and though due on 1858, January 27, was not seen. If it appeared at all, which is doubtful, it could not exceed the 11th magnitude. But at the next due apparition, May 4, it positively did not come at all; for Mr. Baxendell was searching night after night, with his great reflector, and limited it "under $14\frac{1}{2}$ magnitude," as shown by the short red (dotted) lines representing his valuable records, at the very time it was due at a maximum. The August apparition occurred in conjunction, and the star was justly supposed to have "EXPIRED" or died out gradually. But on November 16 it returned, nearly as bright as ever, as shown by the combined observations made at Oxford and Manchester. And lastly, on February 19, 1859, it acquired a maximum equal to any previous

* The red lines in the original diagram are represented by dotted lines. (See Plate I.)

one on record. Here again it is interesting to find the independent observations of the writer, at the Hartwell Observatory, and of M. Goldschmidt at Paris, blending so smoothly together—to form the light-curve. And I may here remark upon the advantage of free intercourse in science. But for the valuable communications of my two friends, I could only tell half my tale, and the curious failure of its appearance in May 1858 would have remained "NOT PROVEN!" Its truant nature is well shown by the circumstance, that out of 162 nights on which it has been sought for, it has been seen only on twenty-seven, and these distributed amongst four observers.

The details of the observations of these five stars, as well as of eight others, which have in fact been the recreations of my leisure hours for some years past, after the discharge of official duties at the Radcliffe Observatory, were to have been published as a supplement to one of the future volumes of the Transactions of that establishment, in which they were mostly made. The untimely death of my venerated Director and friend, M. J. Johnson, Esq., has interrupted this arrangement.

As the various maxima and minima depend upon very different numbers of observations, a systematic and just assignment of the weight or comparative value of each resulting equation has been duly regarded, and is an indispensable consideration in all such investigations.

It is singular how many of the variable stars have *faint companions*, though whether physically or merely optically double, years of accurate measurement can alone distinguish.

The empirical prediction of future changes, by the deduced epochs and periods, is the first fruit, and perhaps for some time, the only yield to be expected from this field of sidereal research. These are, however, so much wanted, that with the approval of my patron, Dr. Lee, and our distinguished neighbour Admiral W. H. Smyth, to whose invaluable experience and ever readily bestowed counsel and encouragement I owe the most grateful acknowledgments, the variable stars form the chief pursuit towards which the resources of the Hartwell Observatory are directed; and an Atlas of the vicinity of every known variable, together with the determination of the standard magnitudes of the most suitable comparison stars in their immediate neighbourhood, is in an advanced state of preparation; so as to relieve amateurs who are inclined to take charge of a few of these interesting and amusing objects, of the only tedious part of the process. Many possessors of small but good telescopes exclaim in despair, "What can I do to be useful with my small optical means, which is not better done elsewhere?" To such I would reply, "Record the changes of some yet undetermined variable star!" It is little gain for all to be occupied on the same objects, because they appear most striking and interesting; plenty yet remain, the elements of variation of which are still unknown; and to supply the first good deductions of this kind ought to satisfy the ambition of any one who seeks to be useful, without incurring the outlay of money, time, and trouble requisite for the pursuit of the more advanced branches of the science.

On the Effects of the Earth's Rotation on Atmospheric Movements. *By* DANIEL VAUGHAN, *United States.*

Though much attention has been hitherto devoted to the motive power concerned in producing the winds, there is still much room for investigations respecting the circumstances which modify its action. From the influence of heat in expanding the air, and the manner in which temperature varies with an increase of latitude, it has been inferred that the lower atmosphere must flow towards the equator, from remote parts of the northern and southern hemisphere, while returning currents roll back above the region of the clouds. On tracing the change which the earth's motion must occasion on such moving masses of air, a very plausible explanation is obtained of the leading phenomena of the trade-winds. But it seems difficult to account for the geographical range of these regular movements of the air; as their extreme limits, even in the Pacific Ocean, extend only a few degrees beyond the tropics, and alter position comparatively little during the different seasons of the year. The difficulty appears greater, when we reflect that, in the torrid zone, temperature is not much affected by an increase of latitude, and must therefore operate with less energy in causing a general circulation of the atmosphere.

My researches show that the chief obstacle to the extension of trade-winds to the temperate zones, proceeds from the diurnal motion of the earth. On the centrifugal force arising from this rotation depends, to some extent, the direction of terrestrial gravity at places between the poles and equator; the equilibrium of our atmosphere is accordingly dependent on it; and if this vast collection of air ceased to partake of the earth's movement, the greater part of it would be compelled to remove from the tropical to the circumpolar regions. In like manner, when the air is moving towards the west, it experiences a reduction of centrifugal force, accompanied by a slight change in the direction in which it is attracted by our planet, and a proportionate tendency to flow towards the pole; while in an eastward movement the effect would be reversed, and there would be a steady deflection towards the equator.

Whenever an extensive portion of our atmosphere undergoes a considerable change of latitude from local variations of temperature, it cannot, at once, acquire the velocity and the centrifugal force necessary for an equilibrium in its new location, and a retrograde movement is a necessary consequence. Accordingly the earth's rotation, instead of disturbing the repose of our aërial ocean, only imposes restraints on the disturbances arising from the action of solar heat. Its resistance to atmospheric movements (supposing friction removed, and the motive power to act in the direction of the meridian) is nearly proportional to the square of the sine of latitude multiplied by the distance the air has been withdrawn from the parallel of the place which has the same velocity with respect to the earth's axis. This rate of variation appears to be approximately correct, whether the air be supposed to preserve its eastward velocity unchanged in its passage towards the equator or the poles, or whether cognizance is taken of the change of velocity, with which the translation must be attended, that our globe may sustain no loss of momentum by aërial commotions. But in the latter case a higher coefficient of resistance will be obtained, though it must be diminished in consequence of the effects of friction. It thus appears that the centrifugal force attending the rotation of our planet, impedes only in a slight degree the extensive movements of the winds in tropical regions; but it becomes a serious impediment to their prevalence on the same scale, in the temperate and the frigid zones.

As the part of the atmosphere which feels most intensely the expanding influence of heat is compelled to ascend, in the vicinity of the equator it flows towards the poles, forming two vast aërial rivers, whose breadth is nearly 25,000 miles at their origin, but is reduced to about 22,000 miles on reaching the parallels of 28 degrees. Such a reduction of breadth would evidently be accompanied with an increase in the depth of the stratum of air, were it not for the decline of temperature; but it cannot fail to augment atmospheric pressure, especially at the place where the progressive movement from the equator is arrested by the resistance from centrifugal force. This occurs between the 25th and 30th parallels of latitude; and here the great pressure, of which the barometer gives manifest indications, causes the air to descend, to roll back towards the equator, and to participate once more in the circulation of the trade-winds. It appears, moreover, that the mere form of the earth must be an impediment to the extension of trade-winds to any considerable part of the temperate zone, where the degrees of longitude diminish so rapidly in length; for the belt of air which encircles the equator could not make a general movement as far as the 60th parallel of north latitude, without swelling to a height wholly incompatible with the conditions of equilibrium.

The aqueous vapour conveyed by the trade-winds is condensed into rain during the ascent of the air at or near the equator; and the evolution of heat attending this condensation must, according to Professor Espy, be regarded as the chief source of power which maintains the great circulation of the tropical atmosphere. He has long ascribed storms to the local condensation of vapour, and he adduces evidence to show that the winds blow to the point at which the most heavy rain is descending; but Dr. Hare attributes this centripetal movement to the constant discharge of electricity, which the moisture of the air enables to escape from great elevations. Now, whatever part heat and electricity may act in these phenomena, the results must be modified in the same manner by the diurnal motion of our globe. As the impediment which centrifugal force gives to atmospheric movements augments with every increase of latitude, it is evident that in our hemisphere the air must be drawn from the greatest distance and with the greatest velocity on the south side of a storm; and this, taken in connexion with the constant eastward deflection of the moving mass in its passage to the north, will account for the superior force of south-west winds in the north temperate zone.

The air pressing from the north and south to the place at which the greatest rain occurs, must be deflected in opposite directions; and on this principle it has been proposed to account for the rotation of storms. But the eastward and westward winds must cooperate in producing the same result, the former being deflected to the south and the latter to the north, from an excess and a deficiency of centrifugal force. The spiral motion, generated in this manner, prevents the atmospheric pressure, at the centre of a storm, from being increased by the influx of the surrounding air, and contributes to make the violent movement extend to the bottom of our aërial ocean.

As the air on the east side of the great vortex cools by retiring from the equator, it becomes less capable of retaining its aqueous vapour, while an opposite effect takes place on the west side, where the temperature of the air increases with the change of latitude. From the greater abundance of rains which accordingly fall on its east side, the focus of a rotating storm must be constantly shifted in an eastward direction; but between the tropics the movement depends on less effective causes, and the course is mainly determined by the direction of the trade-winds. In temperate climates a tendency of the storm to recede from the equator must proceed from the superior violence of south-west winds, to which allusion has been already made. Accordingly the present theory, without involving any new hypothesis, appears to furnish a very satisfactory explanation of the leading facts which meteorologists have discovered, respecting the rotary and orbital movements of tempests in different regions of the earth. The constant change in the position of the focus, to which the whirling mass of fluid is directed, appears to be the cause not only of the east or north-east course which storms take in our climates, but also of the centrifugal motion of the air which observers have occasionally noticed, and which Espy ascribes to the impulse of descending drops of rain.

On a System of Moving Bodies. By A. S. S. Wilson.

Meteorology.

On the Semidiurnal and Annual Variations of the Barometer. By John Allan Broun, *F.R.S., Director of the Observatories of His Highness the Rajah of Travancore.*

In the twenty-second volume of Poggendorff's 'Annales' (pp. 219 and 493*), M. Dove showed, in discussing observations made at Apenrade, that when the tension of vapour in the atmosphere is subducted from the whole atmospheric pressure (for each hour), the remaining diurnal variation of dry air pressure has a period of twenty-four hours like that of the elasticity of vapour itself, only that the maximum of the one occurs at the same time as the minimum of the other, these epochs coinciding nearly also with those of highest and lowest temperature†.

M. Dove has shown that this result may vary under different circumstances; thus in a place far from the sea, to which no sea breeze can make up by day what the ascending current carries away of vapour from the lower strata. the curves of the elasticity of vapour and of dry air will march together; since both fall at the warmest time of the day, the dry air as well as vapour will be carried up by the rising current, and flow off sideways. For a decidedly continental situation, then, we may expect that the maximum of the morning will disappear in the combined pressure measured by the barometer, which will happen for places in the neighbour-

* Cited in M. Dove's paper "Bericht," &c. der Wiss. zu Berlin, Marz 1846, p. 54.
† Ibid. p. 54.

hood of the sea only for the pressure when the elasticity of vapour has been deducted. Between these extremes of sea and continental climates a gradual passage will occur *.

M. Dove's hypotheses (for there are more than one included in this statement) were presented to the English reader first by General Sabine, in a Report on the Meteorology of Toronto, published in the Reports of the British Association for 1844, p. 50, and examined by him with reference to a sea climate, that of Bombay, in the Reports of the British Association for 1845, p. 73.

In the Reports of the Association for 1845, p. 12, the Committee on Magnetical and Meteorological Observations put the question, "Has M. Dove's resolution of barometric fluctuation into two elements received any confirmation?" In the "Bericht," &c. of the Berlin Academy of Sciences (March 1846), M. Dove discusses observations made at Java, and conceives that his discussion answers the question decidedly in the affirmative †.

Mr. Broun maintained in 1846, in his discussion of the Makerstoun Observations, the insufficiency of M. Dove's hypothesis; but as this has been adopted lately by Sir John Herschel in a treatise on meteorology, Mr. Broun considered the time was come for a careful examination of the facts on which M. Dove's method professes to be founded.

Two hypotheses are included in that method:—1st. That the tension of vapour deduced from the psychrometer observations is due to an atmosphere of vapour pressing with a weight equal to that tension. 2nd. That through the action of the solar heat an ascending current of air is induced; the air is expanded and overflows above over colder localities.

In order to test the first hypothesis, Mr. Broun made some observations (in January 1857) on the sea-shore of Travancore, which were compared with observations made in the Trevandrum Observatory eight miles distant. These observations showed that the *variations* of the barometric pressure were to the same amount at both stations, that the difference of temperature was about 0°·8 Fahr.; nearly that due to the difference of heights (about 160 feet), but that the difference of computed vapour tension varied considerably; these tensions were as follows:—

	Tension of vapour.				
	19^h.	22^h.	2^h.	$4\frac{1}{2}^h$.	$9\frac{1}{2}^h$.
	in.	in.	in.	in.	in.
Channavilla	0·645	0·643	0·690	0·692	0·723
Trevandrum	0·543	0·562	0·641	0·669	0·685
Difference	0·102	0·081	0·049	0·023	0·038

The difference of tensions was upwards of one-tenth of an inch at 7 A.M. and less than one-fourth of that quantity at 4 P.M. As this difference would have been shown at the sea-shore nearest to Trevandrum (three miles distant), it was pointed out that the tension of vapour thus determined, depending wholly on the different temperatures of evaporation at the two stations, was quite a local phenomenon, varying with proximity to the source of evaporation, the temperature and the pressure of the atmosphere, and the rate of diffusion of the vapour itself under such pressure. On this ground the hypothesis fails completely. Indeed the diurnal variation of pressure of computed dry air was shown to have the 10 A.M. maximum as well marked at Chunnavilla as the barometric variation. General Sabine had obtained a somewhat similar result from the Bombay observations; and the double oscillation still remaining in the dry air pressure, was explained by a supplementary hypothesis depending on sea and land breezes. It was here noted by the author that the Bombay Observatory was within a hundred yards of the sea, in a position quite resembling that of Chunnavilla Cottage; and that the distinctness of the double maximum and minimum in the calculated dry air pressure, instead of being due to a sea and land breeze, was simply due to the small diurnal range of the computed vapour tension, which in the *arithmetical* operation of subtraction was insufficient to disguise the barometric law. A few miles inland the disguise would have been more marked.

* Cited in Mr. Dove's paper "Bericht," &c. der Wiss. zu Berlin, Marz 1846, p. 54. This is nearly a literal translation of M. Dove's statement.

† Ibid. p. 60.

Mr. Broun then showed the *insufficiency* of M. Dove's method, by a discussion of observations made at Makerstoun in Scotland in 1843-46. In the winter quarter it was proved that, so far from the morning maximum disappearing, the diurnal variation of dry air pressure showed a better marked double oscillation than was exhibited by the barometer. Further, it appeared that the amount of the diurnal oscillation of the barometer had no relation whatever to the amount of diurnal oscillation of vapour tension or of temperature; the sum of the barometric diurnal oscillations at Makerstoun being greatest when the amount of the diurnal variations of vapour pressure and of temperature were least. It was also remarked that there were secondary maxima of vapour pressure which did not show themselves at all in the barometric results; or that when the tension of vapour by the psychrometer observations seemed to increase, the total pressure, as measured by the barometer, gave no symptoms of it.

M. Dove had brought forward as a proof of the accuracy of his method, the statement that in places far in the interior of the Asiatic continent, such as Catherinenburg, Nertchinsk, &c., distant from large masses of water and with dry atmospheres the double diurnal oscillation was not shown in the barometric observations. Mr. Broun pointed out that this should not depend upon the mean dryness of the atmosphere, but upon the diurnal *variation* of vapour tension as computed by the psychrometer. He compared the diurnal variations of vapour tension at Nertchinsk and Makerstoun in 1844, which were as follows:—

	4—5 A.M.	1 P.M.	Range.
	in.	in.	in.
At Nertchinsk	0·122	0·155	0·033
At Makerstoun	0·267	0·301	0·034

As the range is as great at one place as at the other, there can be no better reason (as far as this point is concerned) for the barometric oscillation being single at Nertchinsk than at Makerstoun.

But in order to test the method more perfectly, one of the dryest months (January) of the year 1844 was chosen; in that month the diurnal variation of vapour tension at Nertchinsk was between 0·008 in. at 6 A.M. and 0·017 in. at 1 P.M. The oscillations were compared with those for the same month at Makerstoun in Scotland; the comparison will be best understood by the following Table:—

Oscillations of Barometer and Dry Air Pressures at Nertchinsk and Makerstoun, January 1844.

Station.	Pressure by	8 P.M.	Change.	5 A.M.	Change.	10 A.M.	Change.	1 P.M.	Change.
		in.	in.	in.	in.	in.	in.	in.	in.
Nertchinsk	Barom....	27·830	−0·021	27·809	+0·020	27·829	−0·027	27·802	+0·024
	Dry air...	27·819	−0·018	27·801	+0·015	27·816	−0·031	27·785	+0·034
Makerstoun...	Barom....	29·705	−0·020	29·685	+0·023	29·708	−0·020	29·688	+0·017
	Dry air...	29·501	0·019	29·482	+0·011	29·493	−0·031	29·482	+0·039

It will be seen from this Table that the barometer diurnal oscillations at Nertchinsk, in the interior of a great continent, for the month of January 1844, agreed within a few thousandths of an inch with those for Makerstoun, a quite insular locality; the greatest difference being in the afternoon minimum, which falls ·007 in. more at Nertchinsk than at Makerstoun. The diurnal variation of dry air pressure shows a distinct and well-marked double maximum and minimum like that at Makerstoun.

Mr. Broun concluded his examination of the sufficiency of M. Dove's method, by a discussion of observations made in the observatory of His Highness the Rajah of Travancore at Trevandrum; from which it appeared that the double diurnal maximum and minimum of dry air pressure were shown in the dry quarter, that of land and sea breezes; in the monsoon quarter, that of continuous N.W. winds; and in the means for the whole year; but most distinctly and regularly in the monsoon quarter, when no land and sea breezes are blowing.

With reference to the second hypothesis, that of overflowing currents, it was stated that not only were there no grounds for it, but there were several facts quite opposed it. Among others, it was pointed out that the best marked of the semidiurnal variation of the barometer at Makerstoun in 1843–46, was that for the night (9 P.M. to 9 A.M.) during the winter quarter, when the tension of vapour and temperature of the air were nearly constant.

Mr. Broun now adduced the results of a series of observations made under his direction, by fifteen observers, at Trevandrum, at the base of the Ghats, twenty miles distant; and at three other stations, rising successively on the sides of the Agustier Mallay, by 1500 to 1700 feet, the highest being the Peak Observatory, 6200 feet above the sea-level. These series show completely the insufficiency of all the usual hypotheses.

The following Table contains the mean barometer oscillations derived from a month's hourly observations in the commencement of 1859:—

Period.	Trevandrum.	Kalliad.	Karootha Kay.	Kamellamudy.	Agustier Peak.
	in.	in.	in.	in.	in.
9 P.M. to 3 A.M.	−0·070	−0·074	−0·076	−0·075	−0·082
3 A.M. to 9 A.M.	+0·091	+0·090	+0·093	+0·090	+0·090
9 A.M. to 3 P.M.	−0·126	−0·115	−0·096	−0·082	−0·070
3 P.M. to 9 P.M.	+0·105	+0·099	+0·079	+0·067	+0·062

It appeared from these observations that the night oscillations (that between 9 P.M. and 9 A.M.) had nearly the same value at Trevandrum three miles from the sea, and at different heights on the Ghats twenty miles from Trevandrum; the oscillation being on the whole greatest at the highest station. The day oscillation diminishes as we ascend, the diminution being partly due to the expansion of the atmosphere during the day, by which part of it previously below the upper stations is carried above them.

It seemed probable that the oscillations were chiefly due to an action upon the upper or dry atmosphere, indicating, the author conceived, an electrical or magnetical result.

Mr. Broun proposed in 1857 a theory of the diurnal variations of the barometer, which agreed to some extent with one communicated to him by Dr. Lamont in a letter (dated June 4, 1859), but published elsewhere by Dr. Lamont.

Dr. Lamont's hypothesis was founded on the electrical action of the sun, whereas Mr. Broun's, as at first proposed by him, was founded on the sun's magnetical action; he proposed in the present state of the facts to place both hypotheses under the following general form.

The sun by its electrical action (static or dynamic) on our atmosphere and the earth gives to the atmosphere an ellipsoidal form with the longer axis nearly under the sun; this ellipsoid, following the sun, produces the semidiurnal oscillation of the barometer, the extent of this electrical action probably depending on the relative dryness of the air.

In Dr. Lamont's view, the action is electrical induction on the atmosphere (the sun's electricity supposed positive); in Mr. Broun's view, magnetical induction on the atmosphere and earth; by both the part next the sun is attracted, and on the opposite side repelled, or *vice versâ*.

The author now referred to the annual variation of the barometer, and concluded—

That the annual variation within the tropics was quite a local result, the range of the monthly mean pressures being about one-tenth of an inch for each four or five degrees Fahrenheit of range of monthly mean temperature.

That the mean pressure of the whole atmosphere is greatest in December or January, and least in June or July; this difference being more marked when the computed dry air pressures are considered.

Finally, the author remarked that if the sun's action on our atmosphere resembled its action on the gases of comets, the pressure should become greater as the earth approached the sun, that is in December; but it was believed that the difference found between the pressures in December and June, was chiefly due to the greater humidity of the air in June than in December, by which, according to the hypothesis for the diurnal variations, the electrical action is diminished. According to Dr. Lamont's mode of considering the solar action, the barometric pressure should be *diminished* as the earth approaches the sun. The whole question of atmospheric electricity, and its relation to the electricity of the earth, is, however, in a sufficiently vague state to render a just view of the sun's supposed electrical or electro-magnetical action, if the magnetical view be taken, somewhat indefinite; but whether we suppose the atmosphere positively electrified and the earth negatively, or with M. Peltier, that both are resinously electric, the latter more powerfully than the former, we must consider not only the action on the atmosphere, but also that on the earth, and the vapours which rise from its surface, as well as their reactions on each other.

On the Fall of Rain in Forfarshire. By ALEXANDER BROWN, *Observing Member of the Meteorological Society of Scotland, &c.*

	Arbroath.	Barry.	Montrose.	Hillhead.	Strichen.	Craigton.	Dundee.	Kettins.	Monthly average of stations.
Latitude N.	56° 34′	56° 29½′	56° 42½′	56° 33′	56° 33¾′	56° 31½′	56° 27½′	56° 32′	
Long. W...	2 35	2 47	2 31	2 51	2 49½	2 50	2 59	3 13½	
Altitude ...	65 ft.	35 ft.	15 ft.	500 ft.	500 ft.	500 ft.	100 ft.	240 ft.	
1858.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January ...	0·923	1·25	0·60	1·09	1·15	1·21	1·21	1·51	1·117
February...	1·037	1·09	0·70	1·19	1·31	1·29	0 92	1·20	1·093
March......	1·277	1·23	1·60	1·47	1·50	1·55	1·16	1·20	1·373
April	1·287	1·25	0·85	1·79	1·85	1·92	1·40	1·55	1·487
May	2·093	1·97	1·80	2·00	2·07	2·25	1·80	2·42	2·050
June	1·513	1·32	2·32	1·29	1·44	1·33	3·37	1·77	1·794
July	3·076	3·75	3·10	3·35	3·63	3·44	3·60	6·74	3·835
August ...	2·270	2·44	2·27	2·25	2·45	2·25	2·80	3·10	2·479
September	2·023	2·76	1·85	2·70	2·80	2·73	2·34	2·85	2·506
October ...	2·665	3·28	2·63	3·10	3·23	3·18	2·88	......	2·995
November	1·874	3·01	2·20	3·25	3·40	3·20	2·45	2·18	2·695
December	4·315	3·47	3·00	3·91	4·17	3·95	3·62	3·45	3·735
Total	24·353	26·82	22·92	27·39	29·00	28·30	27·55	27·97 11 months.	27·159

The above Table gives, for the year 1858, the monthly fall of rain at eight stations, where rain-gauges are kept, in Forfarshire, extending from Montrose on the east to Kettins on the west. The distance of these two extreme stations from each other is about thirty miles, and the district embraced by the eight stations comprehends about one-third part of the whole county. The first three stations named in the Table and the last, are four of the Scottish Meteorological Society's stations. The three stations, Hillhead, Strichen, and Craigton, are in the neighbourhood of each other, and situated in the parishes of Monikie and Carmylie around the reservoir at Monikie, from which the town of Dundee is supplied with water. The latitudes and longitudes of the different stations are taken from Arrowsmith's large map of Scotland. The altitude above sea-level of Arbroath and Barry stations is taken from the Ordnance Survey, and the altitude of Monikie reservoir is 440 feet, as found from the survey made by Mr. Leslie, C.E. in connexion with the construction of the Dundee Water-Works; the stations named are higher than the reservoir and estimated as in the Table. The station at Kettins is not far distant from some of the highest hills in the Sidlaw range. The rain-fall there for eleven months is greater than for the whole year at any of the other stations, excepting Strichen and Craigton, which arises from the unusual rain-fall of 6·74 inches in the month of July. For the whole of Scotland, the rain-fall for 1858, as given in the Quarterly Reports of the Scottish Meteorological Society, is 33·91 inches,—greater than that of the above eight Forfarshire stations by 6¾ inches.

The following Table gives the annual rain-fall at five of the above-named stations for six years, from 1853 to 1858, both inclusive, with average annual fall for that period. It will be noticed that the annual fall increases with the altitude of the station above the sea-level.

Years.	Arbroath.	Hillhead.	Strichen.	Craigton.	Dundee.
	in.	in.	in.	in.	in.
1853...............	27·602	33·46	36·46	34·75	31·78
1854...............	20·818	29·06	30·19	31·83	24·31
1855...............	21·026	26·14	27·43	26·66	22·70
1856...............	32·274	39·45	41·49	39·93	35·29
1857...............	23·739	32·04	33·31	32·51	27·53
1858...............	24·353	27·39	29·00	28·30	27·55
Average of 6 years...	24·969	31·51	32·98	32·33	28·19

Remarks on the Climate of Orkney. By the Rev. CHARLES CLOUSTON, *L.R.C.S. Edinb., Pres. Ork. Nat. Hist. Soc. &c.*

Orkney is situated further North than any part of the mainland of Scotland or the Naze of Norway, and nearly in the same latitude as Stockholm on the East, and Cape Farewell on the West; yet its climate is one of the most equable in Britain, and this is ascribed to the effect of the surrounding oceans, and particularly of the Gulf-stream.

From meteorological observations made in Orkney for nearly thirty-three years, tables of which were laid before the Section, it has been ascertained that its mean annual temperature is not only equal to that of the north and middle of Scotland, but even to that of the south border, or 46°·26; while Dumfriesshire is 4° or 5° colder than Orkney in winter, it is above 3° warmer in summer. This arrangement may be pleasant, or favourable to animal life, but it is unfavourable to vegetation, particularly to trees. Evergreens are killed by the sea-spray in winter. The difference between the mean temperature of the warmest and coldest months is only about 17°, never having risen so high as 62°, nor fallen so low as 31°.

That the Atlantic moderates the extremes and elevates the temperature of winter, more than it depresses that of summer, is evident, when we consider that in 1858 its mean temperature was about 3½° above that of the air, which it exceeded during ten months, and only fell below it during June and August. It has not yet been found colder than 43°, and the mean of three years is 49°·56, or more than 3° above that of the air.

In the inland parts of Britain the greatest heat occurs about the middle of July, and the greatest cold about the middle of January; and the months equidistant from these are most nearly of equal temperature. In Orkney, however, January and February are equally cold, and July and August equally warm; and the months equidistant from these correspond most nearly, as March and December.

This retardation of the period of extreme heat and cold is ascribed to the influence of the sea, which is neither so quickly heated in summer, nor cooled in winter, as the surface of the land.

A table was produced showing the mean monthly atmospheric pressure for the last twenty years, which does not show any great peculiarity of climate. It attains its greatest height in May, and gradually descends on each side, the only exception being in September, when it takes a step upwards. The mercury has been observed as low as 27·69 inches, and as high as 30·76 inches, giving a range during these twenty years of 3·07 inches.

A table showing the quantity of rain each month for the last eighteen years was also produced, showing that the mean annual quantity for that time is 36·53 inches at the place of observation on the west side, but it is much less on the east side of the islands. As in the former tables, so in this may be observed a gradation from the minimum to the maximum quantity; thus May has the least rain as well as the highest barometer, and it gradually increases on each side till October, which is the wettest month, September being the only exception.

From a table giving the direction of the wind for thirty-two years, it appears that it blew from the W., S.W., S. and S.E., 6964 days, while from the opposite four points it blew little more than half that time, or 4041 days. Does Orkney owe much of the mildness of its climate to this prevalence of S. and W. winds?

Two other tables were given—one embracing a great variety of particulars regarding Orkney, the other the same particulars regarding all the stations of the Scottish Meteorological Society. From these it appears that the instruments do not show more dampness in Orkney than in the other stations.

Observations on the Natural Obstructions in the Atmosphere preventing the view of Distant Objects on the Earth's Surface. *By* ALEXANDER CRUICKSHANK, *A.M., Aberdeen.*

I wished to determine the frequency with which the daily extreme limits of view from any fixed station, over an extensive range of country, are circumscribed by natural causes, viz. haze, showers, and mist or low clouds. For this purpose I made daily observations about noon, during the years 1856, 1857, 1858, from the vicinity of Aberdeen, on the distance seen along the South Deeside Grampian range of mountains, which run in a S.W. direction from Aberdeen, and of which the main tops are visible in fine weather from that vicinity, at the respective distances of five, ten, twenty, thirty, forty, and fifty miles. These tops are called Clochendichter, Caernmanearn, Caerloak, Mt. Battock, Mt. Keen, and Lochnagar, the last one being nearly in the S.W. corner of Aberdeenshire. They are all nearly in a line, and were taken as fixed points for noting the varying distances seen. It was found that the obstructions to distant vision, caused by showers, and by mists or low clouds, entirely obscured the view at once, at the nearest points to the observer at which they existed. When, however, haze circumscribed the view, it was found to increase gradually, with the distance, beyond the nearest point at which it began to be perceptible, and this was often only one or two miles off, till its density entirely prevented further vision beyond the distance of five miles and upwards.

Taking the average of the observations for the above-mentioned three years 1856, 1857, 1858, it was found that the view, about noon, extended to fifty miles, or to Lochnagar, on ninety-four days during the year; but the state of the atmospheric obstructions to vision at that distance showed that, on many of those days, the view must have reached much further, had the observer been at a higher level. On fifty-two days the view was limited to forty miles, or to Mt. Keen, the nearer hills being also seen, or it was less than fifty miles; Lochnagar, though seen in clearer weather from the point of observation, being rendered invisible by the atmospheric obscurities referred to. On forty-five, fifty-one, thirty-nine, and sixty-nine days during the year, the view at the time of observation was respectively limited to the distance of thirty miles, or Mt. Battock, twenty miles, or Caerloak, ten miles, or Caernmanearn, and five miles, or Clochendichter, more distant vision being completely prevented by the atmospheric obscurities beyond those distances. In fine, on fifteen days in the year, mist and showers circumscribed the view within one mile of the place of observation.

Simultaneous observations in other directions from the point of observation, gave similar results, in as far as the inequalities of the earth's surface permitted a sufficient length of radial view. Had, therefore, the view about noon over the earth's surface extended as far in all directions as in that of Deeside, there would have been visible on an average of 94, 52, 45, 51, 39, 69, and 15 days in the year, portions of that surface included within circles of the diameters of 100, 80, 60, 40, 20, 10, and 2 miles respectively.

From the similar variability of climate throughout Britain, the above results may be regarded as true, or nearly so, of the rest of the island. They show that angles subtended by objects at the distance of fifty miles or more, such as enter into the Ordnance Survey of the country, could not, on account of haze, mist, &c., be observed with sufficient accuracy about noon on more than ninety-four days in the year. There is, however, at that time of the day another very frequent and great obstruction to such observations, viz. the tremor of the atmosphere, on the frequency and amount of which the present observer does not feel qualified to report. But it is well known that, owing to the two causes now mentioned—obscurity and unsteadiness of vision—the Ordnance surveyors, with the whole day at their command, have sometimes been obliged to remain for weeks at a station, before getting a favourable opportunity to observe some of their angles.

Note.—From observations made on the subject of the above paper during the year 1859, the view from the vicinity of Aberdeen was found to be limited to the above-mentioned distances on 128, 47, 31, 41, 30, 76, and 12 days respectively.—Feb. 1860.

On the Diurnal Variation of the Barometer. By T. Davies.

The author examines the effect of the sun's heat on a column of air of the height of the atmosphere about the torrid zone, where the heat is greatest, and the days and nights nearly equal. The main phenomena of the diurnal variation are, he finds, represented by this cause. The communication was illustrated by diagrams, which showed two chief maxima and two lesser maxima, with the corresponding intervening minima, at critical hours of the day.

On Mild Winters in the British Isles. By Prof. Hennessy, *F.R.S.*

The author pointed out the circumstance that the meteorological observations made during the late remarkably mild winter tended to confirm the law which he had already announced in a letter to General Sabine, which appears in the 'Proceedings of the Royal Society' for 1858. This law is, that during mild winters the coast stations exhibit an increase of temperature more than inland stations, and that the temperature on the west and south coasts approaches towards uniformity. In France, as pointed out by M. Liais, the first part of this law is found to hold good, as evinced in the comparative climatology of Cherbourg and Paris. Mr. Hennessy referred these phenomena to an abnormal extension of heat-bearing currents across the Atlantic. The prevaling westerly and southerly winds would, under such circumstances, transfer to our shores a great portion of the warmth which they had received from contact with the heated waters at remote portions of these currents; for the condition of the ocean bathing our shores, would be favourable to the preservation of such warmth in the strata of air passing over its surface. From the greater stability of such currents than those of the atmosphere, and from the important influence they undoubtedly exercise upon our climate, he is led to infer that we are rapidly approaching a period when it may become possible to foretell whether the winter shall be cold or warm by knowing the conditions of temperature and the movements of currents in the Gulf of Mexico and the Atlantic during the summer and autumn.

On the Distribution of Heat over the Sun's Surface. By J. J. Murphy.

On the Aqueous Vapour of the Atmosphere.
By Rear-Admiral FitzRoy, *F.R.S.*

In order to show why this subject was of urgent importance, the author gave a brief description of the origin, nature, and objects of the Meteorological Department of the Board of Trade, which was instituted to collect and publish meteorological observations made at sea; and explained that he now required the opinions of competent authorities as to the best method of publishing a great accumulation of valuable observations. Referring especially to the division of opinions of some scientific men on the question of aqueous vapour, and the reduction of barometrical observations, the Admiral quoted passages from the reports of Col. James and Prof. Patten, printed in the third Number of 'Meteorological Papers' published by the Board of Trade in 1858. Admiral FitzRoy then submitted to the President of the Section that it would be desirable to elicit some authoritative opinions on the subject in question, before he proceeded to other meteorological perplexities which he had in reserve for another occasion.

On Atmospheric Waves. By Rear-Admiral FitzRoy, *F.R.S.*

As so much has been said during the last few years about "atmospheric waves," I would refer to them here. If wind veers round the compass in the course of two or three days (more or less), or is many days in making a circuit—invariably, as it goes round, the barometer rises or falls according to the direction or strength of the wind. Supposing a diagram to represent 36 hours, and divided into spaces of three hours each along the upper horizontal line; while below, points of the compass are shown, from north around by east to north again, and continued to south; and at the side a scale of inches and decimals, from 28 to 31. Then suppose that the wind has gone round the compass once, or say once and a half, as happens occasionally; and that it has been an extreme case of depression, as in a storm. Then, if from (say) 30·3, with the wind at north, a shifting occurs, first towards the north-east, and then onward in the same direction around the compass—as the wind so shifts to the north-east, and is about to shift towards the east and south, the barometer foretells it, or falls beforehand. When the wind is north-east the mercury is lower, probably, than when it was at north. As it gets to the east the mercury falls, and gets lower still at south-east, and falls still more to south and south-west, where it is probably the lowest, because it feels the effects of the south-westerly or equatorial current most then, and may be down, let us suppose, to 28·2 inches. As the wind shifts round to south-west, west, north-west, the column in the tube rises, till, perhaps, the wind is north, or even north-east, when it may be as high as 30·8: it has been known in this country as high as 30·9. As the wind goes round again to the east and south-east and south, the barometer falls as before, and a line or curve traced upon paper, representing these falls and rises, or oscillations of the barometer during a certain time, say these 36 hours, has an appearance like the outline of a wave of water; but as these apparent waves or undulations take place *exactly* as the wind shifts, and proportionally to its strength, and as, if the wind remains in one quarter for some days, or say two or three weeks together, the curve becomes almost a direct line, remaining at about the same elevation, it seems that there is an intimate and immediate connexion between such a curve or wave-line and the oscillation of the mercury, though not *necessarily* between the curve and any undulatory movement of the atmosphere above our heads. If a body of the atmosphere above us swelled upwards, like a wave, and fell again, as some suppose, as it were in "crests" and "troughs," how should we reconcile it with the fact of there being various currents passing over each other in the atmosphere from different directions? Aëronauts who have been up in balloons know that from one stratum of air they passed into another and another, and perhaps a fourth also, moving in different directions. There cannot be *vacancies* between the undulations of various strata of air. These different bodies of atmosphere could hardly be undulating like waves while having spaces between them, and interferences of cross movements. Waves of ocean have only elastic air above them, which does not impede their rise and fall materially; and they are only superficial, not reaching far down.

Were there a raising of any part of the mass of air, the lighter or equatorial portions, or winds, would rise the highest, and would expand; but, according to the "Wave theory" (here controverted), the reverse is the fact; you have the lowest part of the apparent trough of the wave, with the lowest barometer, that is, with the air, which is the *lightest* and most *expanded*, and ought therefore to rise up the *highest*; and you have, coincident with the heavy dry air, the highest part, or what is called the "crest" of the wave. Considering then these facts, and the exact correspondence of the movements of the mercury with the wind's direction, besides noticing the extreme variability traceable in such an atmospheric wave (which can hardly be conceived to be motionless for *weeks*, as in the case of a *steady north-easterly* wind, and then going into extraordinary irregularity during *a day or two*), we are led to the belief and assertion that what are commonly called "atmospheric waves" are rather delusive; and that there are waves in any line indicating oscillations of the barometer, but not such, in the atmosphere itself, as are usually adverted to by the expressions "trough" and "crest."

Mr. Birt drew particular attention to these supposed undulations of atmosphere, by papers read at meetings of the British Association, and by a special Article in the 'Admiralty Manual of Science.' Sir John Herschel, Le Verrier, and other great authorities then countenanced Mr. Birt's theory and apparently sanctioned his opinion. Yet there is so much argument against those views, that even the highest names scarcely warrant their implicit adoption. That there must be undulations in the atmosphere—constituted as it is—cannot be doubted; but that the curve traced on paper, representing the oscillations of a barometer as the wind veers round the compass, corresponds to a mechanical, wave-like undulation of the body of atmosphere, is not proved.

We may demur to it on these grounds. First, the curve so traced on paper varies, not only with the barometer, but with the *direction* of the wind, which is invariably accompanied by change of pressure, consequent on the greater or less action of polar or equatorial current.

Secondly, while the wind remains in one quarter, the curve or line, taken as that of a wave, remains almost unvaried, except in consequence of altered *strength* of wind *or much rain*, which have each a comparatively small effect.

Thirdly, the lowest part of the curve (*called* the trough of the wave) always corresponds to the lowest barometer, or *lightest air*; whereas it is the lightest air that rises highest, as instanced at the equator; and therefore the crest of an atmospheric *wave* (so to speak) ought to be over the place of lowest barometer.

Fourthly, aëronauts always find, and the upper clouds often show currents above, very different from those below. These superposed and successive strata, in rapid cross motion, must tend to destroy undulation. I am aware of what Sir John Herschel has written on this subject (atmospheric waves) in his invaluable 'Essay on Meteorology,' in the last edition of the Encyclopædia Britannica; but with the utmost deference I submit, that his experiment—on the undulations transmitted through successive (coloured) strata of fluids *in a vessel*—did not meet the case of fluid strata moving horizontally, in various directions, across each other.

That there are tidal waves in the atmosphere, caused by the sun and moon, experiment has proved; but that they are *very* small has also been demonstrated. This subject, however, has yet to be investigated, by means chiefly of the accurate barometrical measures instituted and carried on by Government during late years, in many parts of the world, and especially at sea. Such waves as these would follow their causes—in periodic times—and *not*, in utter disregard of sun and moon, only correspond to *direction* and strength of wind.

Meteorological Observations made at Huggate, Yorkshire. By the Rev. T. Rankin.

This was a series of tables and observations on the most remarkable meteorological phenomena observed during the year 1858–59 in Yorkshire, in continuation of a similar contribution continued for many years by the same author. They included observations with tables on barometer and thermometer, wet-bulb thermometer, rain-gauge, winds, aurora, the comet, and other remarkable phenomena, such as thunder-storms.

On Tables of Rain registered at Georgetown, Demerara. By P. Sandeman.

These Tables were constructed with the view of ascertaining what relation, if any, exists between the motion of the moon in declination and the state of the weather.

The idea entertained was that the quantity of rain which fell during the time of the moon's motion in declination, changing from north to south in the northern hemisphere, and from south to north in the southern hemisphere, would be found in excess over the quantity which fell during the time the moon is crossing the equator from south to north, or from north to south. The abstract Table No. 5 shows this to be the case in four years out of ten. In regard to the absolute amount of excess over the ten years, the theory holds; the excess when the moon is over the northern hemisphere being 32 inches, and when it is over the southern hemisphere 31·7 inches. The conclusion of the paper exhibits some points of interest. The author remarked that during the years in which the theory fails are to be noted the following peculiarities:—The rains during 1849 were excessive, amounting to 127 inches; it rained almost all the year, reckoning from the preceding month of November. During the months of May, June, and July of that year, nearly 60 inches fell.

During the year 1851, the rain, instead of being confined as usual to certain months, began to be more distributed over the year. In fact the rainy and dry seasons were scarcely distinguishable.

The year 1854 resembled 1851; and during the year 1855 heavy rains fell during the months of February and March, which is quite unusual; and from August 1855 very little rain fell till May 1856, although the drought was not so great as that of 1845 and 1846.

It is remarkable that it was during 1851 the yellow fever prevailed; and about the year 1854 the cholera appeared in the colony for the first time.

There is an intimate relation between the phases of the moon and its period of crossing the equator.

On the 21st of March the sun is on the equator, and new moon must happen at a period of not more than about fifteen days from that date, either after the 6th of March or before the 5th of April. Taking into account the inclination of the moon's orbit to the ecliptic, the moon cannot be more than twelve degrees from the equator at these times. This the moon will run down in less than two days; so that about the equinoxes the moon must cross the equator on an average about one day and a half before or after new moon. In like manner in June, the moon, if confined to the ecliptic, would always cross the equator at a period after new moon of nearly the same interval, about twenty-two days, on whatever day new moon happened; but owing to the inclination of the moon's orbit to the plane of the ecliptic, the interval is sometimes a day and a half more or less than the average. In fact at any period of the year the number of days after new moon, when the moon crosses the equator, is nearly constant, and would be so if the earth and moon's orbits coincided with the plane of the equator. As it is, the interval for different years at about the same period varies rarely more than two days.

The average number of days for each month, when the moon crosses the equator after new moon, is exhibited in the following Table:—

March	0	September	14
April	25	October	$11\frac{1}{2}$
May	23	November	9
June	21	December	7
July	18	January	$6\frac{1}{2}$
August	16	February	$2\frac{1}{2}$

From the facts which have been elicited from ten years' observations, from 1846 to 1856, taken at Demerara, we must arrive at the conclusion that there are some grounds for the truth of the popular idea, so long and so universally entertained, of the influence of the moon on the weather by those classes whose opportunities lead them to judge of the matter.

If the facts which have been elicited should be confirmed by another series of observations at Demerara, or from series of observations already in existence taken at other localities favourably situated, the existence of an influence of the moon must become a scientific fact, and one the knowledge of which will prove of great importance to the future progress of the science of meteorology. There are various reasons why the popular idea of the influence of the moon on the weather is not appreciated in a scientific point of view. The most prominent one would appear to be found in the circumstance that the influence of the moon on the weather has always been looked for in relation to the phases, whereas it should have been referred to the moon's position with regard to the equator.

The climate of British Guiana is probably the most equable in the world. The greater part of the colony being quite flat, there is nothing to interrupt the free course of the winds, which blow for most of the year from an E.N.E. direction.

The chief atmospheric disturbances take place at the solstices, those at other periods of the year being of a more temporary nature; they must be greatly modified by the state of the atmosphere in adjacent countries. The country being in seven degrees of north latitude, is in the zone of the trade-winds for most part of the year; and having the broad expanse of the Atlantic before it, the changes of the weather are rendered comparatively mild and gradual.

British Guiana is peculiarly adapted for meteorological research, not only as relating to its own climate, but as favourable for the elucidation of delicate meteorological questions, which would render valuable aid to the prosecution of the science in other quarters of the world.

TABLE No. 5.—Showing the Excess or Defect of Rain between those periods when the Moon's motion in Declination is changing, and when it is greatest, or when the Moon is in greatest Declination and crossing the Equator.

Years.	Moon's declination.	Excess.	Defect.	Excess for the year.	Defect for the year.	Yearly amount of rain.
		in.	in.	in.	in.	in.
1846.	N.	5·98	3·70	2·28	......	68
	S.	8·28	4·70	3·58	......	
1847.	N	5·50	5·34	0·16	......	95
	S.	14·45	6·76	7·69	......	
1848.	N.	13·40	4·76	8·64	......	95
	S.	9·63	5·48	4·15	......	
1849.	N.	8·38	14·48	......	6·10	127
	S.	11·00	13·30	......	2·30	
1850.	N.	25·82	5·42	20·40	......	112
	S.	20·44	2·31	18·13	......	
1851.	N.	5·50	6·25	......	0·75	97
	S.	8·67	11·52	......	2·85	
1852.	N.	21·04	3·68	17·36	......	95
	S.	11·15	7·16	3·99	......	
1853.	N.	8·91	8·74	0·17	......	86
	S.	8·65	5·09	3·56	......	
1854.	N.	6·41	14·42	......	8·01	86
	S.	2·97	13·68	......	10·71	
1855.	N.	7·65	14·57	......	6·92	99
	S.	8·31	8·31	......	6·92	

On Thunder-storms. *By* G. J. SYMONS.

On the Reduction of Periodical Variations of Underground Temperature, with applications to the Edinburgh Observations. *By* Prof. W. THOMSON, *LL.D., F.R.S.*

The principle followed in the reductions which form the subject of this communication may be briefly stated thus:—

The varying temperature during a year, shown by any one of the underground thermometers on an average for a series of years, is expressed by the ordinary method in a trigonometrical series of terms representing simple harmonic variations*,—the first having a year for its period, the second a half-year, the third a third part of a year, and so on. The yearly term of the series is dealt with separately for the thermometers at the different depths, the half-yearly term also separately, and so on, each term being treated as if the simple periodic variation which it represents were the sole variation experienced. The elements into which the whole variation is thus analysed are examined so as to test their agreement with the elementary formulæ by which Fourier expressed the periodic variations of temperature in a bar protected from lateral conduction, and experiencing a simple harmonic variation of temperature at one end, or in an infinite solid experiencing at every point of an infinite plane through it a variation of temperature according to the same elementary law. In any locality in which the surface of the earth is sensibly plane and uniform all round to distances amounting at least to considerable multiples of the depth of the lowest thermometer, and in which the conducting power of the soil or rock below the surface is perfectly uniform to like distances round and below the thermometers, this theory must necessarily be found in excessively close agreement with the observed results. The comparison which is made in the investigations now brought forward must be regarded, therefore, not as a test of the correctness of a theory which has mathematical certainty, but as a means of finding how much the law of propagation of heat into the soil is affected by the very notable deviations from the assumed con-

* By a simple harmonic variation is meant a variation in proportion to the height of a point which moves uniformly in a vertical circle.

ditions of uniformity as to surface, or by possible inequalities of underground conductivity existing in the localities of observation. When those conditions of uniformity are perfectly fulfilled both by the surface and by the substance below it, the law of variation in the interior produced by a simple harmonic variation of temperature at the surface, as investigated by Fourier, may be stated in general terms in the three following propositions :— (1) The temperature at every interior point varies according to the simple harmonic law, in a period retarded by an equal interval of time, and with an amplitude diminished in one and the same proportion, for all equal additions of depth. (2) The absolute measure in ratio of arc to radius, for the retardation of phase, is equal to the diminution of the Napierian logarithm of the amplitude; and each of these, reckoned per unit of length as to augmentation distance from the surface, is equal to the square root of the quotient obtained by dividing the product of the ratio of the circumference of a circle to its diameter, into the thermal capacity of a unit of bulk of the solid, by the thermal conductivity of the same estimated for the period of the variation as unity of time. (3) For different periods, the retardations of phase, measured each in terms of a whole period, and the diminutions of the logarithm of the amplitude, all reckoned per unit of depth, are inversely proportional to the square roots of the periods.

The first series of observations examined by the method thus described were those instituted by Professor Forbes, and conducted under his superintendence during five years, in three localities of Edinburgh and the immediate neighbourhood: (1) the trap rock of Calton Hill; (2) the sand below the soil of the Experimental Gardens; and (3) the sandstone of Craigleith Quarry. In each place there were, besides a surface thermometer, four thermometers at the depths of 3, 6, 12, and 24 French feet respectively. The diminution in the amplitude, and the retardation of phase in going downwards, have been determined for the annual, for the half-yearly, third-yearly, and the quarterly term, on the average for these five years for each locality. The same has been determined for the average of twelve years of observation, continued on Calton Hill by the staff of the Royal Edinburgh Observatory.

The following results with reference to the annual harmonic term are selected for example:—

Average of five years, 1837 to 1842.

	Retardation of phase in days, per French foot of descent.	Retardation of phase in circular measure, per French foot of descent.	Diminution of Napierian logarithm of amplitude, per French foot of descent.
Calton Hill.			
3 feet to 6 feet.	....	·11635	·12625
6 „ 12 „	....	·11344	·12156
12 „ 24 „	....	·11490	·10959
Mean	$13\frac{1}{3}$ days.	·1149	·11914
Experimental Gardens.			
3 feet to 6 feet.	....	·11635	·10037
6 „ 12 „	....	·11929	·11304
12 „ 24 „	....	·10617	·10844
Mean	$13\frac{1}{6}$ days.	·11314	·10728
Craigleith Quarry.			
3 feet to 6 feet.	....	·063995	·09372
6 „ 12 „	....	·066903	·06304
12 „ 24 „	....	·066903	·06476
Mean	$7\frac{1}{2}$ days.	·065934	·07384

If Fourier's conditions of uniformity, stated above, were fulfilled strictly, the numbers shown in the second column would be all equal among one another, and equal to those in the third column. The differences between the actual numbers are surprisingly small, but are so consistent that they cannot be attributed to errors of observation. It is possible they may be due to a want of perfect agreement in the values of a degree on the different thermometric scales; but it seems more probable that they represent true discrepancies from theory, and are therefore excessively interesting, and possibly of high importance with a view to estimating the effects of inequalities of surface and of interior conductivity. The final means of the numbers in the second and third columns are, for

Calton Hill	·11702
Experimental Gardens . . .	·11061
Craigleith Quarry	·06988

The thermal capacities of specimens of the trap rock, the sand, and the sandstone of the three localities were, at the request of Professor Forbes, measured by Regnault, and found to be respectively

·5283, ·3006, and ·4623.

Hence, according to position (3), stated above, the thermal conductivities are as follows:—

Trap rock of Calton Hill.	121·2
Sand of Experimental Gardens . .	77·19
Sandstone of Craigleith Quarry. . .	273·6

These numbers do not differ much from those given by Professor Forbes, who for the first time derived determinations of thermal conductivity in absolute measure from observations of terrestrial temperature. In consequence of the peculiar mode of reduction followed in the present investigation, it may be assumed that the estimates of conductivity now given are closer approximations to the truth. To reduce to the English foot as unit of length, we must multiply by the square of 1·06575; to reduce, further, to the quantity of heat required to raise 1 lb. of water by 1° as unit of heat, we must multiply by 66·447; and lastly, to reduce to a day as unit of time, we must divide by $365\frac{1}{4}$. We thus find the following results:—

Trap rock of Calton Hill	23·5
Sand of Experimental Gardens . . .	15·0
Sandstone of Craigleith Quarry . . .	53·5

These numbers show the quantities of heat per square foot conducted in a day through a layer of the material 1 foot thick, kept with its two surfaces at a difference of temperature of 1 degree,—the unit of heat being, for instance, the quantity required to raise 1000 bls. of water by $\frac{1}{1000}$th of a degree in temperature.

On the Establishment of Thermometric Stations on Mont Blanc. By Professor Tyndall, *F.R.S.*

I proposed to the Royal Society some months ago to establish a series of stations between the top and the bottom of Mont Blanc, and to place suitable thermometers at each of them. The Council of the Society thought it right to place a sum of money at my disposal for the purchase of instruments and the payment of guides; while I agreed to devote a portion of my vacation to the execution of the project. At Chamouni I had a number of wooden piles prepared, each of them shod with iron, to facilitate the driving of it into the snow. The one intended for the summit was 12 feet long and 3 inches square; the others, each 10 feet long, were intended for five stations between the top of the mountain and the bottom of the Glacier de Bossons. Each post was furnished with a small cross-piece, to which a horizontal minimum thermometer might be attached. Six-and-twenty porters were found necessary to carry all our apparatus to the Grands Mulets, whence fourteen of them were immediately sent back. The other twelve, with one exception, reached the summit, whence six of them were sent back. Six therefore remained. In addition to these we had three guides, Auguste Balmat being the principal one; these, with my friend Dr.

Frankland and myself, made up eleven persons in all. Though the main object of the Expedition was to plant the posts and fix the thermometers, I was very anxious to make some observations on the diathermancy of the lower strata of the atmosphere. I therefore arranged a series of observations with the Abbé Vueillet, of Chamouni; he was to operate in the valley, while I observed at the summit. Our instruments were of the same kind; and in this way I hoped to determine the influence of the stratum of air interposed between the top and bottom of the mountain upon the solar radiation. Wishing to commence the observations at an early hour in the morning, I had a tent carried to the summit. It was 10 feet in diameter, and into it the whole eleven of us were packed. The north wind blew rather fiercely over the summit; but we dropped down a few yards to leeward, and thus found shelter. Throughout the night we did not suffer at all from cold, though the adjacent snow was 15° Centigrade, or 27° Fahr. below the freezing-point of water. We were all, however, indisposed. I was, indeed, unwell when I quitted Chamouni; but I fully expected to be able to cast off the indisposition during the ascent: in this, however, I was unsuccessful; my illness augmented during the entire period of the ascent. The wind increased in force towards morning; and as the fine snow was perfectly dry, it was driven upon us in clouds. Had no other obstacle existed, this alone would have been sufficient to render the observations on solar radiation impossible. We were therefore obliged to limit ourselves to the principal object of the expedition—the erection of the post for the thermometers. It was sunk 6 feet in the snow, while the remaining 6 feet were exposed to the air. A minimum thermometer was screwed firmly on to the cross-piece of the post; a maximum thermometer was screwed on beneath this, and under this again a wet and dry bulb thermometer. Two minimum thermometers were also placed in the snow; one at a depth of 6", and the other at a depth of 4 feet below the surface; these being intended to give us some information as to the depth to which the winter cold penetrates. At each of the other stations we placed a minimum thermometer in the ice or snow, and a maximum and a minimum in the air. The stations were as follows:—the summit, the Corridor, the Grand Plateau, the glacier near the Grands Mulets, and two additional between the Grands Mulets and the end of the Glacier de Bossons. We took up some rockets, to see whether the ascensional power or the combustion was affected by the rarity of the air. During the night, however, we were enveloped in a dense mist, which defeated our purpose. One rocket was sent up, which appeared to penetrate the mist, rising probably above it; its sparks were seen at Chamouni. Dr. Frankland was also kind enough to undertake some experiments on combustion: six candles were chosen at Chamouni, and carefully weighed. All of them were permitted to burn for one hour at the top; and were again weighed when we returned to Chamouni. They were afterwards permitted to burn an hour below. Rejecting one candle, which gave a somewhat anomalous result, we found that the quantity consumed at the top was, within the limits of error, the same as that consumed at the bottom. This result surprised us all the more, inasmuch as the *light* of the candles appeared to be much feebler at the top than at the bottom of the mountain. The explosion of a pistol was sensibly weaker at the top than at a low level. The *shortness* of the sound was remarkable; but it bore no resemblance to the sound of a cracker, to which, in acoustic treatises, it is usually compared. It resembled more the sound produced by the expulsion of a cork fr m a champagne-bottle, but it was much louder. The sunrise from the summit exceeded in magnificence anything that I had previously seen. The snows on one side of the mountain were of a pure blue, being illuminated by the *reflected* light of the sky; the summit and the sunward face of the mountain, on the contrary, were red, from the *transmitted* light; and the contrast of both was finer than I can describe. I may add, in conclusion, that the lowest temperature at the summit of the Jardin during last winter was 21° Cent. below zero. We vainly endeavoured to find a thermometer which had been placed upon the summit of Mont Blanc last year.

General Physics.

A Proposal of a General Mechanical Theory of Physics. *By* J. S. Stuart Glennie, *M.A.*

The approach of a planet to a sun, iron to a magnet, one particle to another, *may* be the effect of, or conceivable only as the effect of a *pull* of the sun, the magnet, or the first particle; but such a pull, however useful as a temporary metaphysical, or metaphorical conception, is mechanically an absurdity: such approach can be mechanically conceived only as the movement of the planet, the iron, or the second particle in the direction of least pressure as between the sun, the magnet, or the first particle, and some third body.

A somewhat extensive colligation of physical facts has led to the conviction that, by further experimental and mathematical research, attractions and repulsions will be found explicable as expressions of the relations of the pressures between three bodies, a general mechanical theory of physics established, and thus the "persuasion" of Mr. Faraday and the profoundest scientific thinkers, "that all the forces of nature are mutually dependent, having one common origin, or rather being different manifestations of one fundamental power," demonstrated as a truth.

The mechanical conceptions and explanations of phenomena with diffidence offered in this paper, are as yet given, less as a theory, than as a proposal of a way in which a general mechanical theory may be established. And the following is a summary of, perhaps, the principal of these conceptions and modes of explanation.

Atoms are conceived as mutually determining centres of pressure.

Thus, atoms are *not* conceived as particles in a medium or in space, at distances from each other determined by the proportions of the hypothetical forces of attraction and repulsion, but as in contact with, and pressing against each other, while their centres are at distances determined by relations of inward and outward pressure.

For convenience of representation and mathematical calculation, atoms may also be defined as centres of lines of pressure; the comparative length of these lines being taken to represent, not the absolute, but the relative development of the force of the atom.

Matter, or that which resists our force, is conceived as a form of force; and the idea of force is explained by the conceptions of—

Equilibrium—the state of equality among the opposing pressures of a system of atoms (defined as above) or bodies (defined as aggregates of atoms).

Motion—the effect of a difference of polar pressures on an atom or body; determined in direction by the resultant of greatest pressure; in degree (or velocity) by the ratio of such difference; and as uniformly accelerated, varyingly accelerated, or uniform, according as that ratio is constant, varyingly, or uniformly inconstant.

A line of motion—the direction of the transmission of pressure relatively increased at one point, and correspondingly decreased at all others.

Heat and specific heat—the former is conceived as an expression of the relations of the mutual pressures of bodies,—the latter, of atoms.

The solid, liquid, and gaseous states appear deducible from certain conditions of relative pressure between three bodies or atoms.

From the condition of equal transmission in all directions, it follows that, in a system with that condition, an increased pressure in any direction will be, as it were, broken up; hence the ratio of resistance at any point will be greater than if the pressure had been directly transmitted; it will be radially transmitted; and will diminish according to the law of the inverse squares.

The phenomena of static electricity appear explicable as the results of the pressure on each other of heterogeneous bodies, or bodies of less and greater power of resisting pressure. Hence the outward pressure of the one is increased, of the other diminished; and hence positively and negatively electrified balls may be represented, the former as having its own, the latter the lines of pressure of the medium increased.

The poles of dynamic electricity are the ends of a line of motion,—points of greater and less pressure.

The relation of magnetism and electricity is the mechanical consequence in a medium of the lateral diminution of pressure increased at a point.

Conduction and insulation, magnetism and diamagnetism are corresponding antitheses, expressive, under different conditions, of the phenomena resulting from greater or less resistance to the transmission of increased pressure.

The gravitation of any two bodies to each other is attempted to be mathematically explained as the mechanical consequence of the relations of the mutual pressures of the two bodies, and the resistances of the medium or other bodies.

The undulations of light, &c. appear as the consequence in a medium of certain different relations of the outward pressure of two bodies.

Polarization is considered as the condition of a line of motion in relation to a mechanically conceived medium. In electrics, we study the different relations of the *ends*; in optics and thermotics, of the *sides*, of a line of motion.

The problem proposed by this theory for mathematical solution is—what are the conditions of pressure and resistance to its transmission that would produce such and such effects? And this theory would direct experiment to the comparison of the different resistances of bodies to different conditions of increased or diminished pressure.

On the Philosophy of Physics. *By* John G. Macvicar, *D.D.*

The object of this communication is to simplify our first steps in physics, by diminishing the number of considerations which at present stand in the position of independent data or postulates; and more especially, to show that the all-important properties of inertia, elasticity, and gravitation, instead of being unrelated, as is generally supposed, do in reality form a group of properties which imply each other, and are in fact nothing else but uniform phenomena resulting from one and the same law, according as that law is viewed in reference to the substance or the form of a single element of matter, or in reference to a system of such elements distributed in space.

In order to reach this law, the author commences by rejecting from thought all the specific properties of individual objects, so as to be left in possession of that which is common to all. He thus finds Substance or Being; of which he prefers the latter term, as being positive and even absolute in its import, and therefore suitable to build science upon. Moreover, in the very term itself he finds the law, of which inertia, elasticity, and gravitation are the expressions and the results.

Thus the term Be-ing implies that the subject of it both exists and (excluding at present the consideration of living, self-changing Beings or Spirits) continues to be as it is. Now this, expressed dynamically so as to give a physical law, implies *that* which both exists and has the power of repeating its existing state in every successive moment of its existence; or as may be said, *that which* both exists and *assimilates itself to itself in successive moments of its existence* (and that without limitation, and therefore) *through the whole sphere of its agency, and thus assimilates other beings or things within that sphere, more or less, as well as itself.* Whence obviously two grand functions are implied in the operation of this law: *first,* Self-assimilation, implying the permanency of the type of the species, be it chemical element, crystal, plant, or animal; and *secondly,* Mutual assimilation, implying the phenomena of Induction, Generic resemblance among species, and general Harmony in nature. This law the author regards as the impress of the immutability and unity of the Creator in his works. And though there is often (perhaps always) a mechanical apparatus by which it is worked out in nature, yet it may, if found true, be accepted during our ignorance of that apparatus, as a rational explanation of phenomena for which he holds that its relevancy is paramount.

Inertia.—Under the law that has just been laid down this property immediately appears. Thus, given a physical point, unit of matter, atom, or element of mere being, the law of Being (which from its mode of action may also be called the law of assimilation) calls upon that element to continue to be, nay, to be as it has been and is now, to repeat its existing state, to assimilate itself to itself in every successive moment of its being. And therefore if it be at rest, it must continue at rest, unable to leave the place in which it is but through some force applied to it from without. If, again, it be in motion, that is, continually leaving one point in space for the next point adjacent to it, that also it must continue to do in every successive moment of its existence. From which it follows, that not only is the perpetuity of the motion secured, but the form of it is determined. Thus a translation from one point in space to the next point adjacent, is an element of a straight line necessarily lying in some definite direction. But to this, under the law, every successive element of motion must be assimilated. The whole therefore, when viewed in reference to space, must be rectilinear. And for the same reason, when viewed in reference to time, it is obvious that equal portions must be described in equal times. The whole motion therefore must be uniform as well as rectilinear.

Elasticity.—But whatever possesses substance and can be distinguished from the space in which it exists, must also possess form. And in reference to this attribute, the law of Being or assimilation obviously provides that a form once constituted in harmony with that law shall tend to perpetuate itself, shall tend to assimilate itself to itself in successive moments of its existence, and consequently, if partially disturbed, shall make an effort to recover its form and volume, in other words, shall be resilient or elastic. Thus elasticity, instead of being wholly unconnected with inertia, presents itself under our law as the *inertia of form.* And here it admits of being shown that the form of culmination under this law, towards which every other form must tend, and which all forms do attain when there is nothing in their internal structure or position in nature or their history to prevent its development, is the spherical shell or cell.

Gravitation.—But mere beings or things, units of matter or atoms, which, when viewed as individuals under the Law of Being or assimilation, prove to be inert and elastic, must also, when existing as a system under this law, gravitate towards each other; for, as has been stated in the announcement of the law, it is universal and reciprocal. And hence two or more atoms being given within the sphere of each other's agency, but at a distance from each other, it follows that each, while maintaining itself to the utmost, must also tend to assimilate to itself to the utmost all the others around it. Now, although in virtue of the first function of this law (which is to maintain the specific character, the type, in the individual), the amount of mutual assimilation effected in any given case may not be great, in so far as the form and structure of the different members of the system are concerned, and such that they manifest themselves only after long æras, or in some phenomenon of transient induction only, yet there is no bar in the way of their being assimilated, as to the place they occupy, except the inertia of the system. Each member in that system will therefore tend to assimilate all the other members of the system to itself in this respect, that is, to draw or attract them all into its own place, and consequently to itself. And this each must obviously do with a force proportional to itself, that is, to its quantity of being or substance or mass; for of material things we know nothing, and can conceive nothing but as localized, individualized, limited forces, or aggregations of force, more or less. All the members in a system which exist within the sphere of their mutual agency, must therefore attract each other proportionally to their masses. Nor is this all the light which our law throws upon the grand phenomenon of gravitation. It also determines the force of gravitation at different distances from the centre. Thus, conceiving it geometrically and mechanically, which is indispensable when our object is to obtain a geometrical and mechanical expression, we are obliged, under the law of assimilation (as is indeed commonly done under every hypothesis), to conceive of the attractive force of any centre as existing around that centre in concentric spherical shells, their radii and surfaces continually increasing as they recede from the centre. Now these spherical shells, in order to satisfy the law of assimilation, must be all assimilated to each other in the amount of attractive force which they represent; they must be all dynamically equivalent to each other, be they large and remote from the centre of force, or small and near that centre. But if so, it plainly follows, that, when estimated in any one direction or along any one radius, the force must diminish as the spherical surface or the square of its radius increases. But this is the well-known law of gravitation.

Thus the three great properties of matter, inertia, elasticity, and gravitation, show themselves to be intimately and beautifully related, not arbitrarily conjoined, and such that a single conception explains them all.

Instruments, &c.

On producing the Idea of Distance in the Stereoscope. *By* Joseph Beck.

In a view taken through the camera no immediate foreground can be introduced: thus we lose in the photograph an important element in nature for the appreciation of size and distance. In reproducing nature we ought to supply some substitute. This can easily be accomplished. Take an ordinary glass transparent view, and look carefully at it; in some instances the foreground absolutely appears to project into the instrument; and never is it so arranged that the idea of the distance of the foreground of the picture from the edge of the stereoscope is given. Take now a black mat or card, with two holes so cut in it, that when laid on the view, the right eye can see more of the left-hand side of the right picture, and the left eye can see more of the right-hand side of the left picture. It will then be obvious that the excentricity of this mat will indicate a difference of angle; and in proportion as this excentricity is increased or decreased, so the picture appears to advance or recede from the stereoscope; and as the view recedes and distance is given, so the appearance of the real size of nature is obtained.

If the plan is reversed, and the mat is cut so that the right eye sees less of the left-hand side of the right picture than the left eye, we can produce the appearance of the object standing up in the instrument, and in proportion as it approaches the stereoscope, so the size is decreased. In these cases there is no difference in the angle at which the pictures are taken, and yet such vast differences in the apparent size of the picture, showing that whilst the amount of difference of angle is a matter of comparatively but little consequence, the introduction of a prominent foreground, such as mentioned above, enables us to estimate the real size of the object viewed. The carrying out of this plan may be observed in the mounting of Mr. Warren de la Rue's photographs of the moon. Had they been mounted in the centre of circles, they would have appeared as 2-inch balls with beautiful miniature volcanoes and mountain ranges traced upon the surface; but when mounted excentrically, they immediately appear as floating far off in space, every hill and valley, mountain, volcano, or plain assuming grand and imposing dimensions.

On the Stereoscopic Angle. *By* A. Claudet, *F.R.S.*

On the Stereomonoscope. *By* A. Claudet, *F.R.S.*

On the Focus of Object-Glasses. *By* A. Claudet, *F.R.S.*

The researches on this question tended to show the relation between the distances and sizes of objects with the focal distances and sizes of their images, and to find the two points, one before the lens and another behind, from which the distance of objects and the focal distances must be measured, and from which all proportions are in an exact ratio; for it is found that measuring from the object-glass on both sides, double distance of object does not produce one-half of the focal distance, and *vice versâ*. These two points are, first, the point before the lens which produces an image infinitely large at infinite distance; and behind the lens, the point which is the focus for an object at infinite distance, giving an image infinitely small; it is obvious that these two points are on each side the zero of the scale of measure, and it remained to fix the position of another point before the lens, which produces behind the lens an image as large as nature. The two spaces between these points, one in front and the other behind the lens, are perfectly equal, and they are each the unit by which all distances of objects and all focal distances are to be measured. Double the unit in front will give a focus one-half of the unit behind the lens, and one-half of the unit in front will give a focal distance double of the unit behind the lens, and all the other distances in the same proportion; so that, knowing either the distance in front of the lens, or the focal distance, the other distance can be found without having to examine the focus on the ground-glass; the only thing to do being to divide the scale called "the unit of focal distances," in any number of parts corresponding in an inverted ratio with the progression of distances in front of the glass.

On a Changing Diaphragm for Double Achromatic Combinations. By A. CLAUDET, *F.R.S.*

Mr. Claudet explained the construction of his contrivance, intended to reduce or increase the aperture of a double achromatic lens without having to unscrew one of the lenses and without any slit on the tube. This is done by two rings revolving on one another, like the top and bottom parts of a round snuff-box, and each carrying a number of india-rubber stripes, the other end of which was attached on the opposite ring; so that making the ring not fixed in the tube to revolve by an external pinion, the india-rubber stripes were drawn intermixing each other, gradually reducing the aperture until each of them was extending on the diameter of the tube, on which disposition the whole aperture was shut. Mr. Claudet exhibited also the very ingenious pupil diaphragm, invented by Mr. Maugey, optician in Paris.

On an Instrument for exhibiting the Motions of Saturn's Rings. By Professor J. CLERK MAXWELL.

The author exhibited an instrument made by Messrs. Smith and Ramage of Aberdeen, to exhibit the motion of a ring of satellites about a central body, as investigated in his 'Essay on the Motion of Saturn's Ring.' It is there shown that a solid or fluid ring will be broken up, and that the fragments will continue in the form of a ring if certain conditions are fulfilled. The instrument exhibits the motion of these fragments as deduced from the mathematical theory.

On a New Photometer. By the Abbé MOIGNO.

The Abbé said that the instrument could be applied to determine the intensity of the light of the fixed stars, and even of the several parts of the surface of the sun.

On a New Electro-Medical Apparatus. By M. RUHMKORFF, *exhibited and explained by the* Abbé MOIGNO.

The Abbé briefly described Daniel's, and Grove's and Bunsen's galvanic batteries, the chief objection to the two latter being the evolution of nitrous acid fumes. The peculiarity of the instrument he exhibited was, that sulphate of mercury in solution contained in two neat little cups of carbon was used to excite the zinc; a small battery of two cells, aided by a Ruhmkorff's coil, packed up in a small box, constituted the apparatus.

On Becquerel's *Phosphoroscope. By the* Abbé MOIGNO.

On the Phonautograph, an Instrument for registering Simple and Compound Sounds. By the Abbé MOIGNO.

The Phonautograph is an instrument which consists of a large chamber or drum, of a spheroidal form, with a diaphragm or drum-head at one end, which, by a system of levers, works a pen to record the sounds which the form of the chamber causes it to concentrate on the tympanum. The Abbé exhibited a drawing to the Section, which explained the construction of the instrument, and then exhibited drawings showing the actual markings of the pen over a sheet of paper carried past it by clockwork;—1st, when tuning-forks sounding various notes were vibrated in presence of the instrument; 2nd, when several notes were sounded on a diapason pipe; and 3rd, when a person spoke before it. In the first two cases, the recording pen drew such regular curves, that the number of vibrations corresponding to the note as seconds could be counted, and, as the Astronomer Royal observed, they were obviously the curve of sines. In the case of the human voice, the words spoken were written below the corresponding tracings of the pen; and although these were very irregular, yet a marked correspondence could be traced, especially where the words contained *r*, *g*, and other well-marked low or guttural sounds.

Portable Apparatus for Analysing Light. By M. PORRO.

This instrument was a telescope, at the side of which the light to be analysed could be introduced by a slit, and being then reflected down, met a prism of flint-glass, with its remote side silvered, and placed perpendicularly to the axis of the observing or telescopic part; the light then reflected back is dispersed as if by a prism of double the refracting angle of the prism of the instrument, and the dispersion is then measured by a micrometer placed at the focus of the eyepiece.

On an Improvement in the Proportional Compass. *By* Lieut.-Colonel R. Shortrede.

This consists in the introduction of two moveable discs, on which alone the friction takes place, so as to avoid the unequal rubbing of the jaws. This is mischievous, as the jaws invariably become striated circularly at the points of usual setting. Under this unequal action of the jaws they are very apt to shift their position, while at the same time it is very difficult to alter the adjustment by a small quantity when required. These objections have almost thrown the proportional compass out of common use as an instrument for exact work.

On a New Photographic Lens, which gives Images entirely free from Distortion. *By* Thomas Sutton, *B.A.*

The author described a combination by which the effects of distortion are totally obviated, and which gives an image that is mathematically perfect.

The conditions for obtaining an image free from distortion are these:—

1st. The axis of every pencil must emerge from the combination in a direction parallel to that of incidence.

2nd. The axis of every pencil must pass through a certain fixed point.

3rd. The image of every luminous point of the object must be formed at the point where the axis of the pencil meets the focusing screen.

The combination is a Symmetrical Triplet, consisting of two equal achromatic plano-convex lenses, one at each end of a tube, placed with its convex side outwards, and a small double concave lens of equal radii placed exactly midway between them. In contact with the double concave lens a small stop is placed.

It is evident that in this combination a small oblique pencil is incident excentrically upon the front convex lens,—that its axis after suffering deviation passes centrically through the concave lens without suffering further deviation, and that it is then incident excentrically upon the posterior convex lens, from which it emerges in a direction parallel to that of incidence.

The above is true of every oblique pencil, and their axes all pass through a common point, which is the centre of the Symmetrical Combination, and which point is called C.

The 1st and 2nd conditions are therefore fulfilled.

The proof that the 3rd condition is also fulfilled is as follows:—

The focus of an oblique pencil is in every optical instrument a disc of light, and not an exact point. The size of this disc is reduced by using a small stop. When it is *sufficiently* reduced, by using a *sufficiently* small stop the focus upon the screen is said to be good. In that state the ray which passes through C (the axis of the pencil) is one of the rays which compose the small disc or good focus, because C is at the centre of the stop. The focus is therefore at the point where the axis of the pencil meets the focusing screen; and therefore the 3rd condition is fulfilled.

By a fortunate circumstance this Triplet gives an image which is equally illuminated in every part, because the area or base of the oblique excentrical pencil upon the front lens is greater than that of the direct central pencil, and in this way the loss of light from obliquity is counteracted.

Spherical aberration in the direct central pencil is totally corrected, because the negative aberration of the concave lens counteracts the positive aberration of the convex lenses. There is consequently brilliant definition in the centre. At the same time, the marginal definition is as good and the field as flat as that of any lens now in use.

In order to get good marginal definition and the proper flatness of field, the distance between the convex lenses should be about one-sixth of their focal length, and the focus of the concave lens should bear to that of the convex lenses the ratio of about 13 : 8.

On the Angular Measurement of the Picture in Painting. *By* H. R. Twining.

The angle subtended by a picture changes as it is removed further from, or brought nearer to, the observer; and by this change in its position the relation of the near objects to the distant ones becomes altered; so that they cannot be equally correct in both positions of the picture. By means of a small instrument, which may be termed the Hand-goniometer, the student is enabled to fix approximately the distances of objects as represented in a picture, especially in subjects where linear perspective is little concerned. The span given to the two arms of the goniometer fixes the proximity of the picture, by assigning a given number of degrees (about 50) to its apparent width, and thus ensures a conformity between the objects there depicted, and the natural subject which they represent.

The nearest point of the foreground in a level scene averages about 10 yards from the observer, corresponding to an angle of 10° below the horizon; but when the observer is situated above the general level of the prospect, the picture extends downwards to a greater angle below the horizon, so as to include a larger area, or receding plane, between it and the ground line. Figures would generally appear too large if introduced on the very ground line; the size of the nearest usually corresponds with the proportion of human figures at about 15 yards off, corresponding to about 7° from the horizon downwards. The relation of many other points to the horizontal line may be obtained in a similar manner.

A matter of some interest, for marine painters, is the amount of depression of the visible horizon or sea boundary caused by the convexity of the earth; for although a subject of minute inquiry in an artistic point of view, yet it is just sufficiently appreciable to be worth the artist's consideration; since erroneous drawing, with respect to it, may be observed in many of the pictures of coast scenery; a greater amount of dip of the horizon being accounted for by the concealment of objects behind it, than is consistent with truth.

Sir John Herschel, in his 'Outlines of Astronomy,' observes "that two points, each 10 feet above the surface, cease to be visible from each other over still water, and, in average atmospheric circumstances, at a distance of about eight miles;" which limits the horizon of the sea, to an observer's eye situated 10 feet above its level, to a distance of four miles, and assigns to it, at that distance, a real depression of 10 feet only.

With the aid of a glass, the effects of so small an amount of depression become easily appreciable on the sea-side. From the shore, at Eastbourne, I could discern only the sails of a large vessel, which may have been ten miles distant; whereas, from an eminence of about 60 feet above low water, I could distinctly see, with the aid of a telescope, the entire hull, which probably rose 15 feet above the water. But a vessel situated at that distance scarcely measures an angle appreciable to the unassisted eye, and therefore becomes too minute an object to be safely represented in a picture, as partially hidden by the sea's boundary line; in fact, this natural effect could only be introduced in very minute art representations.

It is true, the extremely foreshortened appearances presented by the sea's surface, to an individual on the beach, causes boats and vessels, stationed at considerable intervals from one another, to appear almost in contact, or to seem on the verge of the horizon, although really not at all remote; but this is owing entirely to the illusions of perspective, and cannot be increased to any appreciable amount by the convexity of the water's surface, or the earth's rotundity.

But the case is somewhat different with regard to the amount of depression of the visible horizon, as considered in connexion with the existence of mountains on the coast. The elevation of Beachy Head, amounting I believe to 700 feet above the sea, suffices to cause a depression of the visible horizon, which appeared to me appreciable with the aid of this imperfect instrument; and although this small amount of the horizon's dip does not affect the pictorial character of the sea-view, (which from such a position is remarkable for its vast expanse both horizontally and vertically), yet the convexity of the sea exercises an influence on the outline of very distant mountains which are seen beyond the horizon; for these do not exhibit as they approach the horizontal line any kind of break or change in the direction of their slopes, as is usually observed in the forms of mountains which fall down to the visible edge of the water, but their characteristic curves are cut off, as it were, midway by the line of the horizon which conceals the sea-worn base of each mountain.

CHEMISTRY.

Address by Dr. Lyon Playfair, *F.R.S.*, *President of the Section.*

My predecessor in this chair, Sir John Herschel, drew our attention to the great importance of studying, with increased accuracy, the combining proportions of bodies in the hope of determining the exact numerical relations which prevail between the elements. He justly regarded it as a subject worthy of the most accurate experiment, to ascertain whether the combining proportion of the Elements are multiples of the combining number of hydrogen, as suggested by Prout; cautioning chemists at the same time not to accept mere approximative accordances as evidence of this relation. I have now to congratulate the Section on the publication of the laborious investigations of Dumas on this important inquiry.

It required a chemist of great manipulative skill, as well as of fertile experiment, to obtain combining numbers for the elements upon which a greater reliance could be placed than upon those determined with such admirable precision by Berzelius, that great master of analysis. The atomic weights found by that chemist did not, for many of the simple bodies, confirm the suggestion of Prout as to the multiple relations of these numbers to the equivalent of hydrogen. At the same time the more recent determinations for the atomic weights of Carbon, Silver, and some other elements, so closely coincided with this view, that it was very desirable to extend new experiments to the bodies which had fractional atomic weights assigned to them. In M. Dumas' memoirs there are the results, though not the details, of a large series of experiments on many of the elements. He obtained numbers of precisely the same value as those of the Swedish philosopher when he followed his methods of analysis—numbers which are not the multiple of the equivalent of hydrogen. But when he pursued his experiments upon these same elements, with the new methods of discovery and his own inventiveness, then atomic weights were obtained which corrected themselves from the error inherent in former methods of analysis, and resulted in being multiples of the combining proportions of hydrogen, or in standing in a very simple relation to that number. There is on this point evidence so clear that there is scarcely a chance of deception.

The labours of Dumas, Schneider, Marignac, Pierre, Peligot, and others, have established the relation by recent determinations of chlorine, iodine, bromine, silver, titanium, &c.,–elements differing so much in chemical character as well as in atomic weight, that it is difficult to conceive any fortuitous combinations which could have produced such uniformities in the results of analysis. Hence the general view of Prout, that the equivalents of the elements, compared with certain unities, are represented by whole numbers, seems to be established by recent experiment, although it would be premature to declare that there are no exceptions to the law. We are familiar with many ingenious discussions on the natural grouping of the elements, and the relations of their equivalent numbers to each other. I allude to the papers of Gladstone, Odling, and Mercer, and to the views of Cook, in America. Although these efforts point to important dependences of the elements on each other, we cannot yet adopt them as parts of our scientific system. Another question of a different character, as regards equivalents, has recently received attention. I refer to the proposal to double the equivalents of carbon and oxygen, that is, to raise them from 6 and 8, to 12 and 16 respectively. As these two elements are essentially connected with the whole system of chemistry, the right determination of their equivalents is a matter of extreme importance. Undoubtedly there are cogent reasons which induce many of our able chemists to double the equivalents of carbon and oxygen, and they are well worthy of the calm and deliberate consideration of a meeting like this.

Such an alteration would produce an immense change in the literature of the science, and should only be adopted if the benefit to be derived from it proved to be so great as to justify the inconvenience. This subject will be brought before the Section on more than one occasion. The change proposed has, in a great measure, resulted from the new views of the classification of organic compounds introduced by Gerhardt. The recent brilliant progress in organic chemistry has resulted in the discovery of a vast number of new compounds. A scheme of classification became urgently necessary for them, and the genius of that great French chemist produced a system which has exerted a most important influence on the advancement of science. The comprehensive system planted by Gerhardt has been carefully watered and tended by our countrymen Williamson, Hunt, Odling, and Brodie—until the young plant has attained a most vigorous growth. In a report upon the state of organic chemistry, by one of these gentlemen, we shall have the advantage of tracing its effect on the advance of science. Another of our members who admires the beauty of the plant, and the excellence of the fruit it has borne, fears that it is growing too wildly, and that the pruning-knife might be adopted with advantage. He therefore proposes for our consideration, in a paper which will be laid before you, some modifications of the system of classifying compounds now so prevalent. With the array of talent in our Section, enlisted in favour of Gerhardt's system, there will be full justice rendered to the merits of that lamented philosopher in any discussion which may follow the reading of the paper to which I allude. In conclusion, I have to congratulate the Meeting upon the important muster of English chemists in our Section; although we have at the same time to regret that our cold northern position has prevented our foreign colleagues from joining us, and enjoying that welcome which the warm hearts of our countrymen would assuredly have accorded to them.

On the Solubility of Bone-earth from various Sources in Solutions of Chloride of Ammonium and Common Salt. By Mr. Binney.

On Pentethyl-stibene. By G. B. Buckton, *F.R.S., F.C.S.*

This paper detailed the preparation of a new organo-metal compounded of one equivalent of antimony and five of ethyl. The author stated that great difficulties presented themselves in isolating the new body, from the tendency it showed to split by distillation into ethyl and triethyl-stibene. In this decomposition it imitates the deportment of pentachloride of antimony, which by heat evolves chlorine. The existence of this substance, the author conceived, had some importance, since it confirmed the views lately advanced by some chemists, that the ethyl compounds of antimony and of arsenic form no exceptional cases, but are most naturally referred to the types of antimonious and antimonic acids, &c.

On the Specific Gravities of Alloys. By F. Crace Calvert, *Ph.D., F.R.S., F.C.S. &c., and* Richard Johnson, *F.C.S. &c.*

The study of alloys and amalgams having been made especially with impure or commercial metals, the results obtained have been such that it has been impossible to solve the important question, Are alloys and amalgams chemical mixtures or compounds? It is with the hope of throwing some light on this subject that we have for the last two years been engaged in examining, comparatively, some of the physical properties, such as the conductibility of heat, tenacity, hardness, and expansion of alloys and amalgams made with pure metals, and in multiple and equivalent quantities as follows:—

1 Copper and 1 Tin		1 Tin and 2 Copper
1 „ „ 2 „		1 „ „ 3 „
1 „ „ 3 „	and	1 „ „ 4 „
1 „ „ 4 „		1 „ „ 5 „
1 „ „ 5 „		

By this method we have succeeded in ascertaining, first, the influence which each additional quantity of a metal exerts on another; secondly, the alloys which are compounds and those which are simple mixtures; for compounds have special and characteristic properties, whilst mixtures participate in the properties of the bodies composing them. This method of investigating alloys and amalgams has enabled us to ascertain the metals which combine together to form definite compounds, and those which, when melted together, only form mixtures. Thus, for example, bronze alloys are definite compounds, for each alloy has a special conductibility of heat. Thus the alloy—

	Obtained.	Calculated*.	Difference.
$Sn\,Cu^2$	13·65	19·87	6·22
$Sn\,Cu^3$	15·75	21·37	5·62
$Sn\,Cu^4$	4·96	21·88	16·92
$Sn\,Cu^5$	6·60	22·50	15·90

These same alloys have a specific gravity of their own. Thus—

	Obtained.	Calculated*.	Difference.
$Sn\,Cu^2$	8·533	8·059	0·474
$Sn\,Cu^3$	8·954	8·208	0·756
$Sn\,Cu^4$	8·948	8·306	0·642
$Sn\,Cu^5$	8·965	8·374	0·591

The same fact is also observed in the expansion or contraction of these alloys; whilst, on the contrary, the alloys of tin and zinc being mixtures, conduct heat, have a specific gravity, and expand according to theory, or the proportion of tin and zinc which they contain. Thus for heat—

	Obtained.	Calculated.	Difference.
$Zn\,Sn^2$	15·15	14·90	0·25
$Zn\,Sn$	16·00	15·80	0·10
$Zn^2\,Sn$	16·65	16·95	0·30

Specific Gravity.

	Obtained.	Calculated.	Difference.
$Zn\,Sn^2$	7·274	7·193	0·081
$Zn\,Sn$	7·262	7·134	0·128
$Zn^2\,Sn$	7·188	7·060	0·128

The authors then gave tables showing the specific gravity of various alloys and amalgams divided under two heads:—

I. Those which have a higher specific gravity than indicated by theory. Of this class there were five series, viz. copper and tin, copper and zinc, copper and bismuth, copper and antimony, and tin and zinc,—comprising thirty-one alloys.

II. Those which have a less specific gravity, or expand. Of these there are six series, viz. mercury and tin, mercury and bismuth, mercury and zinc, antimony and bismuth, bismuth and zinc, and tin and lead,—comprising forty alloys and amalgams.

Their researches reveal two important facts; first, that there is one metal the alloys of which always contract, viz. those of copper, whilst all the amalgams expand or have a less specific gravity; secondly, that the maximum expansion or contraction of alloys and amalgams generally occurs in those which are composed of one equivalent of each metal, the exception being those of tin and zinc. But this arises no doubt from the fact, that all the alloys, with the exception of the latter, are compounds and not mixtures.

In conclusion, attention is drawn to the extraordinary contraction or expansion that some of these alloys experience. Thus, for example, the alloy of three of copper and one of tin,

Found.	Calculated.	Difference.
8·954	8·208	0·746

whilst the amalgams of tin expand to nearly the same extent, as shown by these results:—

	Found.	Calculated.	Difference.
1 of Mercury, 1 of Tin	10·255	11·259	1·004

* The principle upon which the theoretical conductibility, specific gravity, and expansion are calculated, is similar to that followed with respect to hardness, for which, see Philosophical Transactions, 1858.

On the different Points of Fusion to be observed in the Constituents of Granite. *By* M. F. BIALLOBLOTZKY.

On the Formation of Rosolate of Lime on Cotton Fabrics in Hot Climates. *By* F. CRACE CALVERT, *Ph.D., F.R.S., F.C.S.*

The author exhibited some pieces of calico which were covered with red stains, and he stated that a short time previously the cargoes of two ships on arrival in India had been found to be extensively damaged by these stains. After a great number of experiments he had found those stains to be due to rosolate of lime, the formation of which he traced to the following cause. Amongst the packing or materials used to surround the bales and protect them from wet and injury, was a kind of waterproof felt made of corded cotton bound together and strengthened by a layer of gutta percha which had been dissolved in *impure* coal naphtha, the cloth thus made having been then pressed between cylinders. Under the influence of the warm and damp atmosphere of India, the hydrate of oxide of phenyle, or carbolic acid, became volatilized, and coming in contact with the carbonate of lime contained in the calico, was transformed into rosolate of lime. The correctness of this result was proved by enclosing pieces of white calico in bottles with pieces of the felt, the calico being uppermost; and also by placing a little carbolic acid at the bottom of the bottles instead of the felt, the bottles being kept at a temperature of 110° Fahr. for several days, when in both instances the calico exhibited red stains identical with those which he had previously found in the goods returned from India.

On Crystallized Bichromate of Strontia. *By* Dr. DALZELL.

On the Economical Preparation of Pure Chromic Acid. *By* Dr. DALZELL.

Dr. Dalzell having experimented on large quantities of material, recommends as the result of his investigation, the process of Traube for the production of the impure acid and its perfect purification by from four to seven recrystallizations, and compression of the products between large porous tiles. He describes the modifications in colour and density which chromic acid presents, according to the process by which it has been prepared.

Before applying the baryta test for its purity, Dr. Dalzell reduces with alcohol and nitric, not hydrochloric acid; and he states that when the solution of sesquioxide was diluted, twelve hours at least should be allowed for the action of the test before the purity of the product was affirmed.

Dr. Dalzell also proposes bichromate of strontia as a means of obtaining pure chromic acid. He gave the particulars of the process for obtaining the strontia salt of absolute purity from carbonate of strontia and commercial chromic acid. Bichromate of strontia crystallizes with three atoms of water, all of which it loses at 212° Fahr. He has obtained from it pure crystallized neutral and acid chromates of many of the metals by employing equivalents of their soluble sulphates.

Dr. Dalzell gave the particulars of the composition of several of the metallic chromates; and referring to the action of bichromate of potash on a solution of chloride of barium, stated that when the temperature of the liquid is raised to the boiling-point, Peligot's salt is abundantly formed. He recommends this as the best method for preparing the bichromate of the chloride of potassium. The author stated that he was at present engaged in further researches on the crystallized chromates.

Dr. DAUBENY exhibited specimens of several varieties of Volcanic Tufa from the neighbourhood of Rome and Naples.

Reports from the Laboratory at Marburg. *By* Dr. GUTHRIE.

On the Fluorescence and Phosphorescence of Diamonds. By J. H. Gladstone, *Ph.D., F.R.S., F.C.S.*

While examining the remarkable chromatic properties of Prof. Way's mercurio-electric light, the author observed, that of four diamonds on a ring, two were beautifully fluorescent, one slightly so, and the remaining one perfectly unaffected in that manner. Some other diamonds were found to exhibit the same phenomenon in this light, though the majority did not. The fluorescence resembled that of bisulphate of quinine, and was produced by the same rays, so that the interposition of a solution of quinine stopped the power of the light to produce this effect. The same two diamonds were found to be fluorescent by the lightning flash. On exposing the ring to the sun and bringing it into a dark place, it was ascertained that the two most fluorescent diamonds were very phosphorescent, and the slightly fluorescent one slightly phosphorescent, while the fourth exhibited neither phenomenon. On examining the long paper of M. Becquerel on phosphorescent substances, published just previously in the 'Annales de Chimie et de Physique', it was found that he had obtained somewhat similar results; the diamond, however, is a difficulty for M. Becquerel, as it forms an exception to the rule that "the fluorescence produced is always of the same shade as the phosphorescence." In like manner with the ring in question, while the fluorescence is blue, the phosphorescent tint is a greenish white, scarcely resolved by the prism, but by the action of absorbent media appearing to be between D and E of the solar spectrum. No blue was observable, even the moment after exposure to the sunshine.

Red or yellow glass interposed between the sun and the diamonds prevented the phosphorescence, while blue glass, similarly interposed, gave rise to a brilliant display, suggesting the idea that the less refrangible rays of the spectrum are positively antagonistic to this power; yet the diamonds become phosphorescent when exposed to the light of a candle. On one occasion, when exposed to the sun's rays through cobalt blue glass, they shone visibly when removed merely into dim daylight. On another occasion, after simple exposure to the sun, they were observed to emit light for an hour and a quarter.

If this phosphorescence be the continuous result of some molecular change wrought on the diamond by light, it would appear probable that the effect would go on increasing with the amount of exposure, at any rate, up to some saturation point. This is no doubt true to a certain extent; but in endeavouring to reach this point, the author found that a long exposure to sunshine diminishes the phosphorescent power of the diamonds. This did not seem to be due to differences in the atmosphere or temperature, or to any diminution of the power of the eye to perceive the phosphorescent light, but to be a property inherent in the stone itself. The effect is a very marked one; and what is specially remarkable, is that the diamond which has thus almost lost the power of phosphorescing is found the next day as sensitive as ever.

On Photographs of Fluorescent Substances. By J. H. Gladstone, *Ph.D., F.R.S., F.C.S.*

It is well known, on the one hand, that the chemical action of light resides mainly in the most refrangible rays, and, on the other hand, that these rays are altered in their refrangibility and effect on the visual organs by fluorescent substances. It occurred to the author that such substances would probably exert little photographic action. Hence he had made two drawings on sheets of white paper, one in an acid salt of quinine, the other in a very pale solution of chlorophyll, and had taken photographs of them. Although the drawing in quinine was quite undistinguishable from the white paper, and the chlorophyll drawing nearly so, when they were viewed in the camera for adjusting the focus, they were strongly marked on the photographic image by the little chemical action that had been exerted by them. The sheets of paper, and the drawings developed on the glass plates, were exhibited, showing that what theory had suggested as probable was true in fact.

On a New Form of Instantaneous Generator of Illuminating Gas by means of Superheated Aqueous Vapour and any Hydrocarburet whatever. By MM. Isoard *and* Son.

The apparatus in question for transforming aqueous vapour into illuminating gas, consists of a steam-boiler without reservoir, into which a very small quantity of vapour is injected every second by means of a small hand-pump, or by a force borrowed from the generator itself. This water, on descending through a serpentine tube, heated to redness, becomes spontaneously reduced to vapour almost in a state of decomposition, in which state the two gases, oxygen and hydrogen, are at the limit of combination and separation. At the place where, and at the moment when this vapour, under a pressure of from seven to eight atmospheres, is about to leave the serpentine tube, a determinate and proportional quantity of mineral pitch, heavy pit oil (huile lourde de houille), coal-tar, turpentine, or any other hydrocarburetted liquid is injected by a contrivance exactly similar to that by which water was introduced into the boiler. The superheated aqueous vapour and the hydrocarburet at the moment of contact give rise to a series of decompositions and recompositions, into the theory of which we shall not at present enter; the result, however, is the transformation of all the gases contained in the water and hydrocarburet into illuminating gas.

This gas next passes into a purifier, where, at the same time, it becomes compressed by several atmospheres; on issuing from the purifier, it is collected in the usual manner in a gasometer, whence it may be distributed at pleasure.

M. Jacobi of St. Petersburg and M. l'Abbé Moigno, who witnessed the experiment, could at first scarcely believe the testimony of their own eyes, though they were compelled ultimately to admit that the small apparatus just described generated per minute almost 1500 litres (53 cubic feet) of very rich gas, which burned with marvellous facility, and produced a very intense white light. We have here literally fire and light extracted from water.

By a simple calculation it may be shown that the quantity of heat contained, theoretically, in the gas furnished by the above apparatus is many times greater than the quantity in the charcoal burned in the furnace; so that if the generated gas were conducted by suitable tubes into the furnace, the generation of gas might be prolonged indefinitely, even though, at the same time, a notable quantity were reserved for external purposes of heating and illuminating. It is scarcely necessary to remark that this is no case of perpetual motion, for the generation of gas only continues so long as water is injected into the serpentine tube and a hydrocarburet through the orifice of this tube.

Now the water and the hydrocarburet possess the force stored up in the latent state, and this force, in order to become *vis viva*, requires a mechanical effort which brings together the vapour and the hydrocarburet.

The illuminating gas thus produced, which is four times as rich as that used at Paris, would not cost a centime per cubic metre (one-tenth of a penny per cubic yard), so that the method would introduce a vast improvement in the economic production of light and heat. In applying the method on a large scale, it is true some difficulties would have to be overcome; the relative quantities of injected water and hydrocarburet would require to be determined experimentally for each hydrocarburet, and kept perfectly constant during the process of alimentation. Again in transporting the gas to a distance by means of pipes above or below ground, care would be necessary in order to prevent decomposition and loss of carbon or richness; but the experiments already made to this end are perfectly satisfactory.

On the Effects of different Manures on the Composition of the Mixed Herbage of Meadow-land. By J. B. Lawes, *F.R.S., F.C.S., and* J. H. Gilbert, *Ph.D., F.C.S.*

Under what might be called the system of concentrated production, more prevalent in this country than elsewhere, the *arable* land of a farm was, of course, subject to the loss of those mineral constituents which were contained in the *corn*, and in the *meat*, that were sold from it. Those of the *straw* of the corn-crops, and by far the larger proportion of those of the *root* and *green*-crops generally, were, for the most part, returned to the arable land. But, in addition to this return, the *meadow-land* attached to the arable farm frequently contributed to the manure applied to the rotation-crops. Moreover, under the system of high farming, cattle-food, and also special or artificial manures, containing certain mineral constituents, will be purchased, and thus enrich the stores of the arable land. It thus happens, that the *arable* land, under good ordinary management, if it do not already produce the maximum average crops which the seasons will allow, will probably require the *additional* use of nitrogenous rather than mineral manures, to bring its yield up to that point.

It is somewhat different with the *meadow-land* of the arable farm. Not only is the amount of mineral constituents removed from a given area of land in an ordinary crop of *hay*, much greater than that contained in what may be called, so to speak, a corresponding *grain-crop*, but the proportion of the mineral constituents which will be returned to the land by the home manures in the case of the meadow, will generally be very much less than in that of the corn-land.

It is very important, therefore, to study the effects of different characteristic manures, both on the *amount*, and on the *composition*, of the meadow-hay crop*.

It was found, that *mineral manures alone* increased the total produce of hay, in the case of the experiments in question; but that they caused the increased development of the highly nitrogenous *Leguminous* plants, almost exclusively—the *Graminaceous* ones appearing to be scarcely benefited at all. *Ammoniacal salts*, on the other hand, increased the growth of the less nitrogenous *Graminaceous* plants, almost to the exclusion of the *Leguminous*. The increase by either manure, used separately, was, however, comparatively very limited. But, by the combination of *both mineral manure and ammoniacal salts*, an increase of about 2 tons of hay had been obtained annually, for several consecutive years; and the produce was almost exclusively *Graminaceous*. It contained, in fact, not 5 per cent. of *Leguminous* and *Weedy* herbage put together. The kinds of the *Grasses* themselves, which were developed, also varied very much according to the manure employed. The proportion of *culm*-bearing flower or seed, and of *leafy produce*, respectively, likewise varied very remarkably.

From the above facts it would be expected, that the *chemical composition* of the mixed produce—or hay, would be very much affected by the manures employed. Such, in fact, was the case. The percentages of *nitrogen*, of *impure fatty matter* extracted by ether, and of *cellular matter* or "*woody-fibre*"—and, of course, of the complementary substances—varied very much. And, looking at the composition in connexion with the known conditions and characters of growth, it was concluded that in such green and unripened produce, high percentages of nitrogen, and of crude fatty matter, were indications of low condition of elaboration, and of comparatively low feeding capacity.

Turning to the composition of the *ash* of the hay, it was found that the percentages of *potash*, and of *phosphoric acid*, were very much increased by supplying these substances in manure. The amounts of these constituents, taken from a given area in the crop, were also very much increased by such supply. The acreage amount of *silica*—a constituent which had not been supplied in the artificial manures—did not increase commensurately. This was the case, notwithstanding that, not only were the larger crops very prominently *Graminaceous*, but the Graminaceous produce itself was in large proportion stemmy.

Where hay was grown for the supply of a neighbouring town, the supply of the necessary mineral—or *soil-proper*—constituents, was generally fully maintained by town manures of some kind brought by return carriage. But, where hay was grown on an arable farm, and mown for consumption by stock, or, still worse, for sale, the return was but too often by no means so complete. It was, indeed, highly desirable that the meadow-land attached to the arable farm should receive a fairer share of the home manures, than was usually, or at least frequently, the case. This was the most efficient, and the most economical means, of keeping up the mineral supplies of the meadow-land at such a point as to allow the growth of the maximum crops which the seasons will allow, by means of specially nitrogenous manures. Without the latter, indeed, little or no increase of the *Graminaceous* produce can be anticipated; whilst, it is by means of such produce, that we must hope to get, in the long run, our largest crops. The question of keeping up the fertility of grass-land by means of sewage, or

* For a detailed account of their results, see—"Report of Experiments with different Manures on Permanent Meadow-land," by the Authors, in the Journal of the Royal Agricultural Society of England, as follows:—"Part I.—Produce of Hay per acre," vol. xix. part 2; "Part II.—Produce of Constituents per acre," and "Part III.—Description of Plants developed by different Manures," vol. xx. part 1; and "Part IV.—Chemical Composition of the Hay," vol. xx. part 2.

other irrigation, was, of course, entirely separate from the one here under consideration.

So far as the *chemical composition* of hay was concerned, it appeared that—the more the produce was Graminaceous, the more it went to flower and seed; and the more it was ripened, the higher would be the percentage of *dry substance* in the hay. Under the same circumstances, the higher will be the percentage of *comparatively indurated*, and therefore *probably effete, cellular* or *woody matter*—and the lower will be that of the *total crude nitrogenous compounds*, of the *impure green fatty matter*, and of the *mineral matter*, in the dry substance. On the other hand, a large proportion of *non*-Graminaceous herbage, over luxuriance, succulence, a large proportion of leaf, and unripeness, were likely to be associated with a small proportion of the *more refractory cellular* or *woody matter*, but with a large one of *nitrogenous substance in a questionable degree of elaboration*, a large one of *impure fatty matter of doubtful nutritive capacity*, and a large one also of *mineral matter*, in the dry substance of the hay.

From the results of the investigation as a whole, it appeared, that the proportion, and the relative feeding value, of the various chemical compounds of which the complex substance—*hay*—was made up, depended on such a multiplicity of circumstances, that, even supposing there were no question as to the proper relationship to one another of the different elaborated compounds in our stock-foods, it would still be impracticable to get a true and unconditional estimate of comparative feeding value of such crude vegetable produce, by the simple determination of the percentage amount of one or two important constituents, as was frequently assumed to be sufficient for that purpose. The next step in advance in such inquiries could only be attained, when our knowledge of the proximate compounds—of lower or of higher condition of elaboration—into which the ultimate constituents of our food-stuffs were grouped, had been much extended; and when the digestibility, and applicability to the purposes of the system, of the various proximate compounds, had been experimentally determined.

On the Analysis and Valuation of Manures. By S. Macadam, *Ph.D., F.C.S.*

On the Organic Molecules and their relations to each other, and to the Medium of Light, illustrated by Models according to the Author's Theory of the Forms and Structures of the Molecules of Bodies. By the Rev. John G. Macvicar, *D.D.*

An analogy of function in the entire series of chemical agents being admitted, it follows that an analogy of structure is to be looked for; and the author of this communication, building upon this principle, proceeded to unfold his theory, which infers that what has been proved of a vast number of molecules is true of them all; and that whether in the actual state of analysis they be decomposable or not, they are all compound and constituted each of its own peculiar group of lesser atoms, the ultimate atom being the same in all. It is not hydrogen, however, that the author looks to as the mother element or ultimate atom, and that which would be obtained from all bodies in the last analysis, if such analysis were possible; not only because such hypothesis is excluded by the fact (which meantime must be respected) that the atomic weights even of some of the most abundant molecular agents in nature (chlorine for instance) are not multiples of that of hydrogen, but yet more, because nature herself presents another element, one with which all space is filled, and whose position in nature is such, that, analogically viewed, it seems the common vapour of all bodies considered as mere matter, viz. the particles of light or of the ether, respecting the existence of which there can be no doubt, as every ray of light (not to speak of the retardations and tails of comets) demonstrates.

The principle on which the author conducts the synthesis of these particles into permanent groups, representing, according to his theory, the molecules of bodies, is that of statical equilibrium or balance of mutual attractions and repulsions, which, however, is always one and the same with the principle of symmetry. And thus, as the first symmetrical species, the first that possesses a single axis terminated by poles which are similar to each other (which demand two atoms), and an equator giving a plane at right angles to the poles (which demand three at least), he obtains a group of five as *the nucleus* of the first molecular species to be looked for in the laboratory—the nucleus, for *the volume* of the molecule is supposed to be determined by an electric and calorific atmosphere, which invests the constituent atoms to a great extent, and which tends ever to be of a spheroidal form, whatever the form of the nucleus.

Now it appears *a priori*, that is, when viewing this first molecular body of five elementary atoms purely in reference to its own structure and to the medium of light in which it is conceived to exist, that it must possess the following properties:—1st. In the fully insulated or individualized state, that is, the aëriform, it must be the lightest of all gases; for it follows from a law which the author communicated to the Physical Section, that equal volumes of different gases are to be expected to contain equal numbers of molecules, or numbers in a simple ratio to each other. 2ndly. It must be pre-eminently elastic; for where there is no loss of heat, we can only suppose a defect in elasticity in a gas to be caused by what we know to cause such defect in other cases, viz. violence done by the compression or strain of the elastic structure. Now of this molecule the structure is the simplest and most stable possible. More than any others, therefore, it is secure from strain, and it may therefore be expected to be eminently elastic under the greatest pressures. 3rdly. It must in relation to its quantity of matter be the most highly refractive and reflective of all molecules; for it is well known and is demonstrated by all aëriforms, that it is between similars that the most intense repulsion takes place. Now this molecule is more similar to the medium of light than any other, its every element consisting of a single particle. Between it and light there will therefore be a maximum repulsion, that is, a maximum reflexion or refraction, as the case may be. 4thly. If, therefore, it be viewed as in the solid state, this molecule would be of a metallic nature, and it may be expected to perform the functions of a metal. Now these are the well-known properties of the first of the laboratory gases so well known by the name of hydrogen. But there is this difference between these properties as obtained experimentally and as deduced from the author's theory. In the former case they are obtained only as so many individual facts with regard to hydrogen, which are empirically or incidentally coexistent in the same body. In the latter they are seen to coexist rationally, to imply each other, and in fact to be expressions, in different points of view, of one and the same structure.

Assuming this simplest of insulable molecules to represent hydrogen, its atomic number and weight is of course 5, from which there results, happily for the author's theory, a remarkable coincidence between the current atomic weights on the hydrogen scale and those which this theory gives, not as conventional like the other, but representative of absolute structure. Thus the tendency in the present day, as it was long ago, is to regard the weight of hydrogen as one-sixteenth of that of oxygen, one-twelfth of that of carbon, &c., and therefore representable by ·5 instead of 1·0, as has been usual. Hence the current tables become adapted to that which this theory requires, simply by moving the decimal point one degree to the right. The equivalent of H being ·5, that of O from 8·0 becomes 80, that of C from 6·0 becomes 60, and so on; care being taken, however, to distinguish well between equivalents and atomic weights, since *the equivalent* of active elements, whose place is usually on the poles of a central body, *consists of two atoms* at least, else symmetry of structure in a single equivalent of the compound is impossible.

It is chiefly in reference to the chemical functions of molecules, however, that this theory shows its value and its power. This was shown in reference to hydrogen in its relations to carbon, of which latter the genesis and model were next exhibited; and which proved to be a five-sided obtuse bipyramid composed of 30 particles of light, as hydrogen is a three-sided acute bipyramid; both viewed in reference to tangent planes. Thus the model of an atom of carbon shows seven regions for the attachment of other bodies, one on each pole, and five on the equator. Charge it fully with atoms of the simplest possible hydrocarbon, viz. CH, and we obtain $C+C_7H_7=C_8H_7$. Now on inspecting works of experimental chemistry, this is seen to be the formula of caoutchouc, the most highly charged hydrocarbon which tropical vegetation alone supplies.

In this molecule the nucleus is an atom of carbon; but nature delights in inversion; as by inverting the vegetable she gives the animal kingdom. Let us take an atom of hydrogen as the nucleus, and charge it similarly with CH. In this case an atom of C being added to each pole, the axis is CH in a double sense, viz. CHC, one atom of H performing the functions of two. But now as to the equator, instead of five regions of union, as there were in the case of carbon, there are only three; whence the fully charged molecule which we obtain in this case is $CHC+C_3H_3=C_5H_4$. Now this, chemistry gives as the elementary formula of the non-oxygenated essential oils (usually written $C_{20}H_{16}$, out of respect to the four-volume theory, but betraying its tetratomic character by the 4HO which appear in the camphors, &c.). And so on with a multitude of hydrocarbons. This synthesis gives them; and they are found to be eminent in nature in proportion as their construction is easy and symmetrical in this theory.

But let oxygen play a part. The first atoms of carbon which must go off from the hydrocarbon $C_5 H_4$, must be those of the equator. Now these are, as has been stated, three in number, leaving $C_5H_4-C_3=C_2H_4$, a beautifully constructed and balanced molecule, leading us to expect it abundantly in nature. And there it is abundant, being the formula of marsh-gas. Most interesting also are its chemical functions being a very stable nucleus. Thus add to each pole an element of syrup (simple hydrate of carbon, CHO, which in the molecular form determined by the pentagonal form of C, requiring as it does the dodecahedron, gives $C_{12}H_{12}O_{12}$), and instead of marsh-gas we have alcohol. Instead of an element of syrup, add to each pole (of C_2H_4) one of carbonic acid, CO_2, or one equivalent $C_2 O_4$, and instead of alcohol we obtain acetic acid. Add carbonic oxide instead, and we obtain aldehyde; and going into regions where nitrogen abounds, instead of carbonic oxide add nitrous oxide, and we obtain urea, $NO+C_2H_4+NO=C_2H_4N_2O_2$, and so on.

And here the doctrine of substitution beautifully presents itself; thus in C_2H_4, or C_2HH_3, there are three atoms of H which are appendages to the equator, and can obviously cede their places to chlorine, &c. without any destruction of symmetry. Hence, instead of C_2HH_3, we may have C_2HCl_3=chloroform. Instead of aldehyde, $C_4HH_3O_2$, we may have $C_4HCl_3O_2$=chloral. Instead of acetic acid, $C_4HH_3O_4$, we may have $C_4HCl_3O_4$=chloracetic acid, &c. The relation of urea and uric acid (considered as monobasic) also appears, and the therapeutic problem assumes a definite form. Thus instead of urea, $C_2HH_3N_2O_2$, we have $C_2HC_3N_2O_2=C_5HN_2O_2$ uric acid, and so on, the substitutions being often easy and such as nature suggests, while the series of the chemist are too often expressive rather of what is possible to nature than what is natural.

On the Action of Air on Alkaline Arsenites. By J. McDonnell.

On Corne *and* Demeaux's *Disinfecting and Deodorizing Powder. By the* Abbé Moigno.

On Matches without Phosphorus or Poison. By the Abbé Moigno.

The Abbé Moigno exhibited a Nephelogene capable of being adapted to many Chemical, Therapeutic, and Hygienic purposes.

New Process of Preserving Milk perfectly pure in the Natural State, without any Chemical Agent. By the Abbé Moigno.

To preserve milk for an indefinite period is an important problem, which in France has been solved in three different modes. M. de Villeneuve was the first to preserve milk, solidifying it by the addition of certain solid ingredients, but it was no longer, properly speaking, milk. M. de Signac preserved it by evaporating the milk till it became of the consistence of syrup, rendering it a solid mixture of milk and sugar; still it could not be called milk. M. Maben also preserved it by excluding the air, and exposing it to an atmosphere of steam about 100° Cent.—thus depriving it of all the gases which it contained, and then hermetically sealing the filled bottles in which it had been heated. When about to leave for Aberdeen, I opened a bottle which had been closed by M. Maben on the 14th of February, 1854; and after a lapse of five years and a half, I found it as fresh as it was the first day. M. de Pierre has greatly improved the discovery. The means which he employs to effect the preservation of milk is still heat; but heat applied in some peculiar way, by manual dexterity, first discovered by a Swiss shepherd. All that I am allowed to state is that the effect of this new method of applying heat is to remove a sort of *diastore*, or animal ferment, which exists in milk in a very small quantity, and which is the real cause of its speedy decomposition. When this species of ferment is removed, milk can be preserved for an indefinite period of time in vessels not quite full, and consequently exposed to the contact of rarefied air, a result which was not effected by the process of M. Maben, or rather that of M. Gay-Lussac, as they completely expelled those gases which otherwise would have rendered it sour. I have such full confidence in the success of M. de Pierre's process, that I had not the least hesitation in bringing along with me from Paris to Aberdeen a large vessel containing five gallons of milk, fearlessly trusting it to railroads and steam-boats, thus exposing it to all the incidents of the journey. I am so confident of the success of the process, that I pour out the contents of this large vessel into Scotch glasses with the conviction that I am giving to the ladies and gentlemen of the British Association a milk as natural, as pure, and as rich as when it was taken from the cow in the fertile plains of Normandy. May this potion, so sweet and so pure, be a symbol of those sentiments of benevolent affection, which France, flourishing and enlightened, entertains towards her noble and great sister England! Owing to its greater specific lightness cream ascends to the top of the vessel, but it can be easily made to diffuse itself through the milk by slightly shaking it before uncorking the bottle. As the vessel is not quite full, a small quantity of butter may have been formed, and the milk may have become somewhat less rich, but it will still be pure and natural milk without any strange taste. Thanks to the progress of science, of which I am happy to be the representative, France can yield with profit to England her fruits, her vegetables, her eggs, and now offers her prepared milk for the wants of the army and navy, having nothing to fear from the longest voyages, nor from the excesses of heat and cold.

Quantitative Estimation of Tannin in some Tanning Materials. By Messrs. Mulligan *and* Dowling.

On Marsh's *Test for Arsenic. By* W. Odling, *M.B., F.R.S., F.C.S.*

Marsh's test depends upon the production of arseniuretted hydrogen when arsenical substances are in presence of nascent hydrogen. The author showed that numerous and varied bodies, including animal tissue, vegetable tissue, the organic matter contained in ordinary earth, preparations of copper and mercury, and oxidizing salts, prevented the formation of arseniuretted hydrogen, and thereby defeated the action of Marsh's test. As a mode of separating the arsenic from these interfering substances, the author recommended the process of distillation with muriatic acid, whereby arsenic in the form of terchloride of arsenic is isolated in a form suitable for testing by Marsh's process.

On the Composition of Thames Water. By W. Odling, *M.B., F.R.S., and* A. Dupré, *Ph.D., F.C.S.*

The general conclusions were as follows:—The amount of dissolved matter, organic and mineral, is greater in high than in low water, in consequence of the contamination of the high water with sea-water—greater in summer than in winter, in consequence of the greater contamination with sea-water in that season, dependent upon the diminished volume of the fresh stream-water. In the winter and early spring, when the quantity of stream-water is great, the presence of sea-water scarcely makes itself felt in the high water, even at Greenwich; or, in other words, there is very little difference in the saline matter of low and high water; but in dry weather this difference becomes more and more marked, and is noticeable higher and higher up the river. Early in the present year, the existence of sea-water in the river was very perceptible, so much so, that even at Wandsworth a difference between high and low water was observed, comparable to that which existed at Greenwich during the winter months. During corresponding periods, the average amounts of residue in high and low water at

Lambeth, were found to be about half as much as the average residues yielded by high and low water at Greenwich respectively. The summer averages at Lambeth corresponded very closely with the winter and spring averages at Greenwich. The percentage amount of suspended matter in the river was found to be twice as great at low as at high water. At low water at Lambeth, the amount of dissolved matter, mineral and organic, is greater at the sides than in the middle, showing that the pure stream-water cuts for itself a central passage through the foul stagnant water at the sides. The same action, though in a much less marked degree, takes place at high water. The up-cast flow, largely contaminated with sea-water, forces for itself a central passage through the stagnant sides. Another point of interest was the difference in composition between the surface water and the deep water. During the flow, the sea-water runs up underneath the river water, and although a complete mixture of the two layers eventually takes place, yet a difference of composition between the top and bottom layers may occasionally be recognized as high up as the Thames Tunnel. The effect produced upon the quality of Thames water by a heavy rain-fall was also illustrated.

On a New Mode of Bread-making. *By* W. Odling, *M.B., F.R.S., F.C.S.*

The vesicular character of ordinary bread results, as is well known, from the development of carbonic acid gas uniformly throughout a mass of fermenting dough, whereby a loose spongy texture is imparted to what would otherwise be a dense sodden lump of baked flour and water. In fermented bread the carbonic acid gas, generated within the substance of the dough, is a product of the degradation of certain constituents of the flour, namely the starch and sugar. In Dr. Dauglish's newly invented process, the carbonic acid gas is produced independently and superadded to the flour, which consequently undergoes no degradation whatever. Carbonic acid, stored in an ordinary gas-holder, is pumped therefrom into a cylindrical vessel of water, whereby the water becomes charged with the gas. This carbonic acid water is mixed, under a pressure of 100 lbs. on the square inch, with the flour, and the resulting dough, which becomes vesicular on the removal of the pressure, is divided into loaves, and baked in a travelling oven. The advantages of the new process are:—1st. Its cleanliness. Instead of the dough being mixed with naked arms or feet, the bread, from the first wetting of the flour to the completion of the baking, is not even touched by any one. 2nd. Its rapidity. An hour and a half serves for the complete conversion of a sack of flour into baked two-pound loaves. 3rd. Its saving of labour and health. It substitutes machine labour for manual labour of a very exhausting and unhealthful character. 4th. Its economy. Despite the heavy prime cost of the apparatus, yet the use of carbonic acid is found to be cheaper than that of yeast. Moreover the waste of the saccharine constituents of the flour, necessary in the old process, is avoided in the new one. 5th. Its preventing any deterioration of the flour. In making fermented bread from certain varieties of flour, the prolonged action of warmth and moisture induces a change of the starchy matter of the flour into dextrine, whereby the bread becomes sodden and dark-coloured. This change is usually prevented by the addition of alum; but in operating by the new process, there is no time for this change to take place, and consequently no advantage in the use of alum. 6th. The character of the bread. Chemical analysis shows that the flour has undergone less deterioration in bread made by the new than in that made by the old process. The bread has been tried dietetically at Guy's Hospital and by many London physicians, and has been very highly approved of.

On some New Cases of Phosphorescence by Heat. *By* Dr. T. L. Phipson, *of Paris.*

Some years ago M. Schœnbein showed that metallic arsenic becomes phosphorescent when its temperature is raised to a certain degree. Lately, M. Linnemann remarked that potassium and sodium were phosphorescent in the dark when freshly cut. The phenomenon is doubtless owing to the rapid oxidation of these metals when exposed to the air. The light emitted by sodium is greenish yellow, that of potassium is of a redder tint. I have had occasion to examine sodium whilst phosphorescent; its light is very feeble, and is only seen upon the surface freshly cut with a knife, and exposed to the air. This phosphoric light, like that of potassium, lasts for a few minutes only at the ordinary temperature of the atmosphere; but at a temperature of about +70° (Centigrade), the light emitted by sodium nearly equals that given out by phosphorus itself.

I have lately observed also that copper, native sulphuret of copper, and silver are notably phosphorescent by heat. With copper the fact is most striking. In order to observe the phenomenon, one or two grammes of copper should be melted before the blowpipe in a cavity made in a piece of charcoal. As soon as the copper is thoroughly melted (at the inner flame) it glows with a greenish yellow phosphoric light, similar to that of the glow-worm. On cooling a little it rapidly loses this property, and at the same time a molecular change is observed on the surface of the metal. Native sulphuret of copper (Chalkosine) is likewise phosphorescent when melted before the blowpipe. Silver becomes slightly phosphorescent only for an instant on cooling, just before it leaves the liquid state.

I have found also that the mineral Lepidolite is quite as phosphorescent by heat as fluor-spar. But to see this phenomenon perfectly, it should be viewed through a piece of glass coloured blue by oxide of cobalt. When seen in these circumstances, the phosphoric light of Lepidolite is very fine; and, when seen through the cobalt glass, the phosphorescence of fluor-spar is far more brilliant than when observed with the naked eye.

This mode of experimentation is probably applicable to all substances that are phosphorescent by heat.

Composition of the Shell of Cardium edule *(Common Cockle). By* Dr. T. L. Phipson, *of Paris.*

The specimens analysed were taken on the coast of Ostend (Belgium). The best of five analyses gives for their composition:—

Water	1·10
Organic matter	4·44
Carbonate of lime	92·93
Phosphate of lime	0·12
Sulphate of lime	0·34
Magnesia	0·13
Peroxide of iron	0·41
Alkalies	traces
Silica	0·53
	100·00

Composition of a recently-formed Rock on the Coast of Flanders. By Dr. T. L. Phipson, *of Paris.*

This rock, which I described some time ago in the 'Comptes Rendus' of the Academy of Sciences of Paris (23rd March, 1857), and which has likewise been mentioned in the pages of 'The Geologist,' vol. i. 1858, London, as being deposited daily from the sea, at about a league from the coast of Ostend, is of a light grey colour. I have lately submitted it to analysis. It presents the following composition:—

Water and organic matter	2·5
Sand...... 57·4, Grey clay 6·0	63·4
Carbonate of lime	30·8
Magnesia (small quantity), Phosphate of lime (small quantity), Alumina (small quantity)	1·7
Peroxide of iron	1·6
	100·0

Certain samples of this rock have a peculiar stratified appearance. It contains fragments of peat, on which it lies, and recent shells, *Cardium*, *Mya*, *Mactra*, &c., in a fossil state.

It is a curious fact that the well-known Fontainebleau sandstone which presents the rhombic crystals of calc-spar, having been recently analysed by my friend M. Pisani, gives likewise 63 per cent. of sand and 30 per cent. of carbonate of lime *.

I would also notice here, that a rock very similar in appearance to the one mentioned in this note, is preserved in the mineralogical collection of the Jardin des Plantes of Paris. It is called "*Grès de Beauchamp*" (Seine et Oise); it contains both marine and freshwater fossils, and has in every respect the same external appearance as the rock discovered by me on the coast of Flanders.

On Soluble Silicates, and some of their Applications. By FREDERICK RANSOME.

The writer gave a history of the discovery of the soluble silicates, and of the various researches and experiments of Dr. Fuchs of Munich, and of Professor Kulman of Lille, and of the several applications of these silicates of Steriochony, to the various branches of manufacture, and to the effects of their combinations with lime, whether carbonate, sulphate, phosphate, or caustic; but described more in detail the value of their applications in the manufacture of artificial stone, and in the preservation of natural stone, &c. from decay. In the manufacture of artificial stone, he stated that the soluble silicate of soda or potash was mixed with siliceous sand and other similar materials, and after being thoroughly incorporated together, the mixture was forced into suitable moulds, and afterwards burnt in a kiln, by which operation the soluble silicate combined with an additional quantity of silica, which was supplied by the sand, &c. with which it was incorporated, and became converted into an insoluble glass, firmly agglutinating all the various particles together into a solid, compact substance, in all respects resembling the finest qualities of natural sandstones. Mr. Ransome produced some specimens of his manufactured stone to the meeting, showing that the material was capable of receiving the most delicate impressions from the most elaborate designs, and that, unlike all other plantic materials which are subjected to a red heat, it retains all its sharpness of outline, and is not liable to contraction or distortion in the process of manufacture. He also gave an account of an interesting series of experiments recently conducted in the testing-house of Her Majesty's Dockyard at Woolwich, for the purpose of ascertaining the relative properties of his artificial stone, as compared with the natural stones usually employed in the construction of buildings; and showed that its power of resistance to steady transverse strain was represented by 100, whilst that of

Darley Dale stone was	81
Of Gumshill stone was	37
Of Portland stone was	33
Of Aubigny stone was	31
Of Bath stone was	13
Of Caen stone was	12

At the same time, a block of this material, 2-inch cube, sustained a weight of 21 tons; whilst a similar block of Darley Dale stone sustained only 16½ tons—thus illustrating its suitability for purposes of construction. In the application of soluble silicates to the preservation of natural stones, &c., Mr. Ransome explained the details of his process, which consists not merely in the application of a soluble silicate, as described and adopted by Professor Kuhlmann and others on the Continent, and which Mr. Ransome stated he found to be utterly ineffective in this country, being liable to removal by rain, or even by the humidity of the atmosphere; but consisted, first, in treating the stone, &c. with a solution of silicate of potash or soda, and afterwards with a solution of chloride of calcium, or chloride of magnesia; by which means a double silicate, or silicate of lime, or silicate of magnesia, was immediately formed in the pores and structures of the stone, &c.,—which double silicate possessed

* It appears evident from these facts, that, in nature, 30 parts of carbonate of lime are sufficient to fix or agglutinate twice their weight of sand, &c. This is doubtless effected by a process of slow crystallization.

the most indestructible and most strongly cohesive properties, enveloping every particle of the stone with which it came in contact, producing an extraordinary amount of hardness, and hermetically sealing all the pores with an indestructible mineral precipitate without in the slightest degree destroying the natural characteristics of the stone. Specimens of stones so treated, and samples of the solutions employed, were submitted to the meeting; and Mr. Ransome exhibited an illustration of the principle upon which his process is based, by taking the two solutions, viz. silicate of soda and chloride of calcium, both perfectly clear, and nearly colourless, and by mixing them in equal proportions in a glass; a solid substance (silicate of lime) was immediately produced, the chlorine combining with the soda, forming chloride of sodium (common salt); the calcium at the same time combining with the silica, forming silicate of lime. Mr. Ransome stated that the process had now been in operation for nearly three years, and had been eminently successful; that, amongst other places, it had been applied to some buttresses at the new Houses of Parliament, to the Royal Pavilion at Brighton, to the Baptist Chapel in Bloomsbury, and to the Custom-House at Greenock; and that it is now being applied upon Craigends House, Paisley, and upon Lennox Castle, near Glasgow. Mr. Ransome also read a professional report he had received from Professor T. H. Henry, F.R.S., in reference to a series of experiments made by him in order to test the merits of the process, by which it was shown that pieces of Bath and Caen stone, when placed in very dilute sulphuric acid, were soon deeply corroded all over, and "became entirely broken up, falling into fragments," whereas pieces of the same stones, after being treated by Mr. Ransome's process, and placed in the same solution for an equal length of time, were "unacted upon, retaining all their sharpness of outline, having lost nothing in weight."

Notes on the Current Methods for Estimating the Cellular Matter, or "Woody-Fibre," in Vegetable Food-stuffs. By M. Thomas Segelcke, *of Copenhagen.*

It is well known that when vegetable substances are treated with solvents—such as dilute acids, alkalies, alcohol, and ether—an insoluble residue remains. This residue possesses *similar characters* though obtained from apparently very dissimilar bodies. Whether from wood, or from green vegetable matter, such as grass, its properties are very nearly identical; and, if the process of solution have been carried far enough, the residue, from whatever source, will have the *same elementary composition.*

It would thus appear, that this insoluble matter is a definite chemical compound; and, from other considerations it is concluded, that it exists, as such, in plants, and is not a mere product of the action of the solvents on their original material. It possesses the form and structure of the tissues of the original vegetable substance; and appears, in fact, to be the chief material of which the *cell-walls* are made up. The names of "Cellulose," and "Woody-Fibre," have, therefore, been given to it.

Owing to the great extent to which the matter in question occurs in vegetable food-stuffs, and, to the obvious conclusion, that, from its insolubility, it will probably be indigestible, and therefore innutritious, it is of great importance to establish some easy means of determining its amount in such substances.

Cellular Matter being obtained from vegetable substances by the use of various solvents successively employed to remove the compounds associated with it, chemists were naturally led to adopt similar means for its quantitative estimation. Accordingly, a number of methods have been employed, the main feature in all of which has been the alternate treatment of the vegetable matter with acids and alkalies. It will be obvious, that the accuracy, and the conformity, of results attainable by the various methods, must depend upon the degree in which Cellular Matter is really insoluble in the solvents used. By many experimenters, the perfect insolubility of Cellulose appears to have been regarded as an established fact. Thus, Peligot, a very careful investigator, considered he had a sufficient check on the strength of the sulphuric acid used as a solvent, if it passed through a paper filter without breaking it. Nor did he determine whether the whole of the Cellulose obtained after the action of the acid, remained insoluble when subsequently treated with alkali.

But, although the alternate action of acid and alkali upon vegetable matter may leave Cellulose undissolved, and thus serve as a means of its preparation, there is in this no evidence that it is absolutely insoluble, and that the *whole* of it existing in the substance so treated, has remained undissolved. The recently discovered action of an ammoniacal solution of oxide of copper proves that Cellulose exists in different states of aggregation, or induration, in some of which it dissolves readily in this solution, whilst in others it appears to be quite insoluble in it. May not, therefore, Cellulose in these different states possess different degrees of solubility when treated with acids and alkalies? Again, there is no proof that the Cellulose which remains undissolved after the limited action of these agents, will do so when the action is continued for a considerable length of time. Indeed, the custom of late years, of designating the Cellulose in Food-stuffs as—*young* and *old*—*soluble* and *insoluble*—*digestible* and *indigestible*—seems to indicate a general opinion that the term Cellulose, as hitherto employed, either includes several distinct bodies, or one that occurs in different states.

The importance of this subject led me to attempt to solve some of the questions involved, by means of direct experiment.

A sheet of Swedish filtering paper was divided into five parts, which were respectively treated as follows:—

No. 1—digested, for half an hour, at 160° to 180° Fahr., with a mixture of 1 vol. oil of vitriol, and 2 vols. water.

No. 2—*boiled*, for half an hour, with very dilute acid.

No. 3—boiled, for half an hour, with an alkali-solution containing 1 per cent. alkali.

No. 4—after treatment with acid as No. 1, boiled with alkali as No. 3.

No. 5—after treatment with acid as No. 2, boiled with alkali as No. 3.

The result was, a loss upon Nos. 1, 2, and 3, of from 1 to 2 per cent. This, however, is not more than might be due to the unavoidable loss in decantation.

Nos. 4 and 5, on the other hand, suffered a loss of from 8 to 12 per cent. A part of this was doubtless due to the same cause as that operating in experiments 1, 2, and 3; but I cannot imagine that the loss I witnessed of this kind can account for the whole of that which occurred in experiments 3 and 4. In fact, I cannot doubt that a considerable portion of the loss in the latter cases, was owing to a change effected by the *acid* on a part of the Cellulose, *by which it was rendered soluble in the alkali.*

Besides this evidence against the assumed stability of Cellulose itself, the complete separation from it of the matters associated with it in vegetable products, is by no means so easy as it is generally described to be. The Cellulose I obtained by following the principal methods that have been proposed, was in no case entirely free from nitrogen. How far it may be possible to obtain it pure I shall not now consider. But, I may state, that even when the action of the solvents was carried far beyond that to which the substance is subjected in the process of analysis, some nitrogen still remained with the Cellulose.

It would appear, therefore, *that determinations of Cellulose made by alternate treatment with acid and alkali, can only be accepted as approximate.*

The question arises—how far the approximate results obtained by the different methods that have been employed, are likely to be comparable with one another? To determine this, a series of experiments was arranged with a view to show the effect of *each of the solvents usually employed*, and also, separately, that of each of the attendant conditions of *concentration*, *temperature*, and *time of action.*

In all cases finely ground hay was the material operated upon; and, in each set of experiments, the effect of the variation of one single condition was made the point of inquiry. It should, too, be observed, that in none of the experiments did the degree in which the several conditions were employed, reach the limit that is found to be recommended as proper for the determination of Cellulose.

The influence of variation in the *strength of the acid*, was the first point I endeavoured to determine. To this end, equal quantities of the finely-ground, and dried hay, were *boiled*, for a quarter of an hour each, with equal volumes of dilute sulphuric acid, the strength of which was different in each experiment. The undissolved residue was in each case well-washed, and then boiled, for a quarter of an hour, with a dilute solution of potash, containing 1 per cent. of the hydrated alkali (KaO, HO). The emaining insoluble matter was thoroughly washed, dried, and weighed. The *time action* of both the *acid* and the *alkali*, the *temperature*, and the *strength* of the *alkali* were therefore alike in all cases. The *strength of the sulphuric acid* was the only condition varied.

The following Table shows the strength of acid used in each case, and the percentage of insoluble Cellulose obtained:—

TABLE I.

Strength of Acid used.	Per cent. insoluble Cellulose obtained.
1 volume oil of vitriol, to 256 volumes water.	34·0
1 volume oil of vitriol, to 128 volumes water.	31·9
1 volume oil of vitriol, to 64 volumes water.	29·8
1 volume oil of vitriol, to 32 volumes water.	27·5
1 volume oil of vitriol, to 16 volumes water.	26·7

It may be mentioned, that the strength of acid used by Wolff, in determinations of Cellulose, was that of 1 vol. oil of vitriol to 117 water; and that used by Peligot was that of 1 vol. oil of vitriol to 2 vols. water.

The next point investigated was the effect of variation in the *time of action of the acid*—all other conditions remaining the same throughout the series of experiments. The strength of acid was that of 1 vol. oil of vitriol to 2 vols. water; and the temperature at which it acted was from 165° to 185° Fahr. The strength of alkali was that of 0·5 per cent. potash; the temperature was that of the boiling-point; and the time of action of the alkali was half an hour.

The effects of variation in the *time of action* of the *acid*, are shown in the following Table:—

TABLE II.

Time of action of the Acid.	Per cent. insoluble Cellulose obtained.
½ an hour.	28·0
¾ of an hour.	27·3
1 hour.	26·6
1½ hour.	25·0

Experiments were next made to show the effects of variation in the *strength of the alkali*. In these cases the acid used was a mixture of 1 vol. oil of vitriol and 64 water. The temperature of the acid's action was the boiling-point; the time a quarter of an hour. The product so obtained, was well washed, and then boiled, in each case for a quarter of an hour, with a solution of alkali, the strength of which varied in the different experiments from 1 to 4 per cent.

The amount of the insoluble Cellulose obtained, varied, according to the *strength of the alkali*, from 28·9 to 27·0 per cent.

It remained to show the influence of variation in the *time of action of the alkali*.

Experiment proved that, all other conditions remaining the same, variation in the *time of action* of the *alkali* of from a quarter to half an hour, gave a variation in the amount of insoluble residue of from 28·9 to 27·9 per cent.

All the above experiments were arranged to ascertain how far the approximate results obtained by the different methods recommended for the determination of Cellulose, are likely to correspond with one another. It is clear, from the results given, that there can be no correspondence except by mere accident. The results published at various times by chemists, cannot therefore, with any propriety, be compared with one another.

It is only possible to obtain fairly comparable results when all variation in method is rigorously excluded. To what extent correspondence may be calculated upon, when uniformity in the conditions of the experiment is maintained, may be seen from the following results of three determinations of Cellulose in the same substance, made *at different times*, but *by exactly the same method*.—

1st experiment, 26·9 per cent. 3rd experiment, 26·7 per. cent.
2nd experiment, 26·7 per cent.

From the results that have been recorded, the following conclusions seem fairly deducible:—

1st. That, *by the action of sulphuric acid upon Cellulose*, the latter is probably, to some extent, *rendered soluble in alkali*.

2. That the removal from the Cellulose of the *whole* of the accompanying *nitrogenous matters* is not attainable by the methods hitherto recommended for its estimation.

3. That *comparable results* can only be obtained when the *strength of the acid*, the *strength of the alkali*, and the *temperature*, and the *time* of their action, are alike in all the estimations.

It will be observed, that the question of the relation of even comparable or corresponding results obtained under such conditions as above indicated, to the *total amount* of Cellular Matter in its various modifications, and that of how the latter may with certainty be determined, remain as yet unsolved. The satisfactory elucidation of these points will obviously require an extended experimental inquiry. At present, we must be satisfied with having shown—that results hitherto obtained by varying methods, cannot legitimately be compared with one another, and on the other hand, with pointing out (which I now proceed to do)—how comparable results, in regard to Cellular Matter of a given degree of insolubility or induration, may, in practice, be attained.

(*a*) The sulphuric acid used, must be sufficiently dilute to allow of the vegetable substance being *boiled* with it without anything like charring; and, on the other hand, it must be strong enough to give a fluid which can, with care, be filtered. The best results hitherto obtained, have been by using a mixture of 1 volume of oil of vitriol to 16 volumes of water.

(*b*) The best *temperature* to adopt for the action of both the *acid* and the *alkali*, is that of the *boiling*-point; which, with the same strength of solution, will, of course, always be the same. No other temperature is so easily maintained constant.

(*c*) The *time of action of the acid* may be regulated by bringing it to the boiling-point, then plunging the substance into it, noting the time of introduction, and taking care to maintain the boiling until the time fixed on has expired—a quarter of an hour is that which I have usually adopted. The mass should now be collected on a filter, and washed. The readiness with which the filtration proceeds will be the greater, in proportion as the acid is strong, or the boiling prolonged.

(*d*) The *action of the alkali* may be regulated by washing the product of the last process from the filter into a beaker, adding water to make up a given volume, and then, when the whole has been brought to the boiling-point, introducing a small measure of a concentrated solution of the alkali of known strength. The small amount needed will not stop the boiling; whilst the strength should be so regulated, as to bring the whole volume to that of 1 per cent. alkali. This strength, looking to the filtration, seems upon the whole to be the most desirable. The *time* of action is, of course, reckoned from the moment when the alkali was added; and the boiling is then continued for the desired period—say a quarter of an hour.

As soon as the adopted time for boiling has expired, the whole should be thrown upon a filter, and the residue well washed with water. Towards the last, a few drops of very dilute sulphuric acid should be added to the contents of the filter—just sufficient to make the washings affect the colour of litmus. The mass is now again washed with water. Finally, it is washed off the filter, dried in a basin at 212° Fahr., and weighed in a small covered beaker.

It should be stated, that this preliminary inquiry on the subject of the determination of the Cellulose, or Cellular Matter, in vegetable Food-stuffs, was conducted in the Rothamsted laboratory, in connexion with an investigation by Mr. Lawes and Dr. Gilbert, on the influence of variation in manuring, and in climatic circumstance, on the composition of the mixed herbage of meadow land. The quantity of substance usually operated upon, was about 10 grammes of the finely-ground hay. 600 septems* was the volume of the acid, and also that of the subsequently employed dilute alkaline solution†.

* A septem measure is that of $\frac{1}{1000}$th of a pound avoirdupois = 7 grains of water.

† By following the directions given in the text, there will probably be obtained more closely agreeing duplicate and triplicate determinations, than those embodied by Mr. Lawes and Dr. Gilbert in the Report of their experiments (Journ. Royal Agric. Soc. Eng. vol. xx. part 11). The *mean* results will, however, I think, correspond very closely in range, in the two cases.

On the Supply and Purification of Water.
By THOMAS SPENCER, *F.C.S.*

The author stated that, from an extensive practice in relation to the chemistry of water for the supply of towns, he became convinced that the available quantity of pure water in these islands was gradually decreasing, whilst it was evident the demand for this primary necessary of life was undergoing an almost corresponding increase; in short, that in the more cultivated districts the supply was every year becoming less capable of meeting the demand.

After pointing out various facts bearing on this result, the author proceeded to consider the purification of water.

The opinions of the best authorities with regard to the probability of effecting the purification of water by any artificial means, were summed up at the conclusion of the report drawn up by the Government Commissioners, "On the Supply of Water to the Metropolis." These gentlemen there said that "whatever substances may be employed in filtering beds, water *cannot be deprived of matter held in solution* by any practical modification of the process of filtration." This was the state of the subject when entered on by him. His object, from the beginning, was to discover the mode by which nature converted impure coloured surface water into colourless spring water, the operation being apparently one analogous to filtration. His first experiments were made with a view of throwing some light on the philosophy of filtration itself as ordinarily practised, having some reason to believe that the process, when most effective, did not so much depend on mechanical principles as was generally supposed. To determine this point, a series of experiments was related to the Section. They resulted in showing that properly conducted filtration (*i. e.* where the gravitating power of the water is not in excess) depends on a lateral attractive action exercised by the sand or other medium through which the process is performed, in addition to the downward action of gravitation. His next object was to discover what bodies in nature exercised this attractive power the best. After trying a number of experiments with various descriptions of rocks and minerals, all of which were described to the Section, he found that those containing protoxide of iron (even where it was chemically combined with other substances) effected the filtration of water from even suspended impurity better than any others. Acting on the idea thus suggested, he found that the same oxide, when isolated in the state of "magnetic oxide," not only freed water from turbidity more effectually than an equal thickness of sand, but effected its decoloration with marvellous rapidity. On the other hand, the earthy substances entering into the composition of the same rocks, such as silica and alumina, when isolated, were, in the latter respect, perfectly *inert*. From this it was evident that the protoxide of iron, as magnetic oxide—a substance which enters into the composition of so many rocks—was one of nature's chief agents of purification. Here the author referred to a series of experiments he had previously made, which resulted in showing that the commonly received opinion, that light and air *alone* effected the purification of water, was partially erroneous. For example, he had put coloured bog water into shallow glass pans, in which it was fully exposed to both these agencies for several weeks—evaporation being compensated by distilled water—but without any change becoming apparent in its colour. This result, so contrary to what he was led to expect *à priori*, induced him, at the time, to refer the natural oxidizing process to the agency of some other body which probably exercised a catalytic action on atmospheric oxygen, and thereby induced this gas to combine with the noxious impurities it met with in the water. Nor was he mistaken in this surmise, as the results so amply related in the paper, together with the experiments exhibited to the Section, sufficiently proved. A most striking experiment was made with some bog water, darker in colour than ordinary porter, which had been procured from the soakings of an Aberdeenshire peat bed. *When brought into contact with the oxide, it was deprived of its colour almost instantaneously, and carbonic acid substituted in its place.*

To appreciate this result, it is to be remembered that no known agency had been able to effect a similar one before. The excess of carbonic acid found in spring water has hitherto never been understood, though henceforth it will be easily accounted for. Since soft water had become so much an object for manufacturing purposes, to effect the decoloration of that of bogs had remained a practical problem, the solution of which had been often sought for by chemists. Not only was it now evident that this water could be deprived of all traces of colour, but it was rendered bright, clear, and perfectly free from taste by one simple operation. Above all, the means by which the change was effected were exceedingly simple. The coloured bog water was merely poured into a glass vessel containing a layer of about five inches of a mixture of equal parts of coarse sand, and a hard ferruginous substance, perfectly magnetic, when it issued forth with considerable rapidity, quite colourless and tasteless, and sparkling with carbonic acid.

It was here stated by Mr. Spencer that the action of the oxide was far from being confined to the decoloration of bog water alone; it equally operated on every impurity to which water was subject; even that of the London sewers it rendered harmless, and void of odour and taste. Besides which, it had resulted from experiments of Professors Brande and Clark, made recently for the Corporation of Liverpool, as well as Mr. Spencer's own, that *soft water on being treated by the magnetic oxide had no action on lead.*

Perhaps the most extraordinary circumstance was, that *the magnetic filtering medium itself suffered no deterioration after any period of operation.* Of course, if its surface was fouled with slimy impurity, it required washing. Its province was confined to force the oxygen, always present in the water, into combination with the impure organic matter, and thus *convert it into carbonic acid,* which gas, he need hardly say, conferred freshness and salubrity on all waters in which it was found. In these results the occult action of catalysis was, for the first time in the history of science, brought at will into artificial every-day operation. In explanation of the action, the author entered on the received notions of what was really understood by the term "catalysis." He thought it might be satisfactorily shown that the substances inducing this action did so in virtue of a power to alter the molecular arrangement of the bodies they came into contact with—as a magnet alters the arrangement of iron filings, even at a distance. Moreover, he believed he was in a position to show that the phenomenon itself was strictly identical with electro-polarization.

In the experiments exhibited, there could, he believed, exist no doubt, that in effecting the decoloration of the water the magnetic oxide attracted the oxygen found therein to its surface, and when there it necessarily became polarized. Whilst in that state, and *only whilst in that state,* it combined with the organic colouring impurity to form a new substance. But the most startling circumstance he had to relate was, that his further experiments went strongly to show *that oxygen, when in this state of polarity, was neither more nor less than ozone*—that fugitive body, of hitherto doubtful origin, which had become so much identified of late with atmospheric salubrity. This novel proposition Mr. Spencer illustrated by an experiment, which exhibited to the Section a larger amount of atmospheric oxygen converted into ozone—by the action of the magnetic oxide on the alcoholic solution of gum-guaiacum—than perhaps had ever been witnessed in the same compass before. The red solution was instantaneously changed, as if by magic, into a deep indigo colour. Though the President evidently had not leaned to the author's theory, this unlooked-for proof of it elicited his admiration. The author stated that this was only one of several modes he possessed of demonstrating the same view of the question, viz. that ozone was atmospheric oxygen polarized by simple contact with the magnetic oxide, or with any other body possessing similar magnetic power. A still stronger proof was, that the poles of a galvanic battery immersed in the guaiacum solution of alcohol also produced in it the blue colour of ozone, *but only at the oxygen pole.* But what he ventured to believe amounted almost to confirmation of this view was, that a similar effect was *not* produced in the solution if made with absolute alcohol; water was therefore essential, plainly that its oxygen might undergo polarity, or, in fact, ozonification.

Mr. Spencer further stated that, according to his experiments, he had found that most if not all mineral substances in nature containing protoxide of iron exercised this power of ozonifying oxygen beyond others. No matter whether this important oxide was locked up in chemical combination with other bodies, still its peculiar power was more or less exercised through the solid covering. He thought therefore that the existence of ozone in the atmosphere need be no longer a problem, his experiments having proved that air while passing over substances of this character became ozonified—by contact alone. Henceforth it would be easy to account for the salubrity of some winds as compared with others. At all events, the experiments he had intended to have brought before the Section demonstrated that oxygen, when in this state of induced polarity, combines with the noxious organic impurities of the atmosphere, and *converts them into carbonic acid*. It would also be evident that the adventitious electricity of a thunder-storm could have but small share in producing the amount of polarized oxygen or ozone required for the purposes of nature. But the ferruginous suboxide was not the only one that exercised this important function, as several other metallic suboxides, which he enumerated, partook of the same power, though in less degree. Peroxide of iron (ordinary rust), on the other hand, or metallic iron, was perfectly inert. In short, the suboxides of all magnetic metals exereised this power, in degree; whilst those that belonged to diamagnetic metals, such as the oxide of tin, not only did not do so, but actively exerted an opposing action—thus realizing ozone on the one hand and anti-ozone on the other. He also found that several gum resins and tars exercised a similar though feebler power over oxygen.

The author gave an account of a new compound magnetic body which he had succeeded in making, to enable him to carry out the purification of water on a large scale. Though the magnetic oxide he had obtained from the white carbonate of iron was very effective, yet it had a tendency to be reduced to fine powder by attrition. He became apprehensive therefore that this circumstance might ultimately interfere with the rapidity of his filtering operations. This led him to seek some mode of procuring an equally effective though less friable body. After various experiments, he had succeeded beyond his anticipations. By very simple means, he had obtained a magnetic body combined with carbon from the hitherto refractory Cumberland hæmatite. This new compound body, which is thus added to metallurgical chemistry, consists of iron, oxygen, and carbon—an equivalent of each; its atomic number is therefore 42. Specimens of it were exhibited to the Section. It appeared very hard, and when polished had a black metallic lustre. It is highly magnetic, and was said to be as incorrodable as gold or platinum. Its purifying powers were stated to be very great. It can be manufactured cheaply. Mr. Spencer, as its discoverer, had named it Protocarbide of Iron. He stated that it was not always necessary in practice to have an equivalent of carbon combined with the oxide, as a smaller proportion conferred the requisite hardness, in which case it was prepared more quickly; but, in making, if kept at a low red heat along with uncombined carbon for a longer time, the combination took place in equivalent proportions.

Notes on a Gold Nugget from Australia. By Prof. J. Tennant, *F.G.S.*

Gold was found first in quantity in Australia in the year 1850; this consisted chiefly of small scales and lumps obtained from various washings, and only amounted altogether to a few pounds troy.

In 1851 the nuggets began to be received; the first of any size is in my hand; it contains about 9 ozs. of gold mixed with quartz, being a waterworn specimen. £50 was asked for it. They then began to arrive in sizes varying from one to five and six lbs. weight.

1852.—John Bull Nugget was exhibited to the public in London for some time; it weighed 45 lbs. 6 ozs.; when melted, it yielded gold to the value of £2500.

1853.—A piece of quartz containing gold, brought over in the 'Sarah Sands,' was melted in July, and yielded gold to the value of £5532 7*s*. 4*d*.

1854–57.—Various specimens, varying from £1000 to £2000 in value.

1858.—The large nugget called the "Blanche Barkly Nugget," weighing 1743 ozs., nearly 146 lbs., was melted August 4th by Messrs. Brown and Wingrove, and yielded gold to the value of £6905 12*s*. 9*d*.; only about 22 ozs. of impurity.

This was exhibited several months at the Crystal Palace, Sydenham.

The "Welcome" nugget, of which the model before us shows the exact size, was brought over in the 'Salffolk,' and received in London in June last. It was found June 11, 1858, at Bakery Hill, Ballarat. The weight is 2217 ozs., or 184 lbs. 9 ozs., and it is now in the possession of Messrs. Dangleish, White, and Hankey, of Great St. Helen's, Australian merchants. I expect it will be melted in the course of next week.

Its supposed value is about £8640: thus 2217 ozs. − 57 loss (about) = 2160 × 4 (value of gold per oz.) = £8640.

Unless the Government, or some person taking a great interest in these matters, would secure it, I should like to see it in one of our national museums, being the produce of one of our most important colonies.

Note.—This nugget was melted September 22, 1859, and yielded gold to the amount of £8376 10*s.* 10*d.*

On the Comparative Value of certain Salts for rendering Fibrous Substances Non-inflammable. By F. Versmann, *F.C.S., and* A. Oppenheim, *Ph.D.*

As nitrogen forms a constituent element of the animal fibre, carbonate of ammonia is among its gaseous products of decomposition, and prevents the animal fibre from burning with a flame and from communicating ignition. The vegetable fibre, however, if decomposed by heat, evolves gaseous hydrocarbons and oxide of carbon mixed with only little carbonic acid, and the danger arising herefrom is the principal reason why paper is frequently replaced by parchment, and wood by stone, iron, &c. But as the use of cotton and of linen increases by necessity from year to year, it is desirable that means should be employed for preventing the danger of conflagrations arising from these highly inflammable substances. Glue and albumen, if introduced into the vegetable fibre, besides injuring the appearance of the same, prove to be useless for the subject in view. They contain only as much nitrogen as the animal substances from which glue is made, viz. about 18 per cent. Urea, however, containing a large proportion of nitrogen, is efficacious, if an amount of 28 per cent. is introduced into a piece of muslin, which consequently contains only 10·2 per cent. of nitrogen in the shape of an animal substance. But for all practical purposes we must look for an expedient among the number of inorganic salts, and this has been done for a considerable time. In 1735 already a patent for preventing substances from flaming was granted to one Obadiah Wild, who applied a mixture of alum, borax, and vitriol, principally for making non-inflammable paper for cartridges. A complete list of the literature on anti-flammable expedients will be given in another place. It must be mentioned, however, in this abridgement, that Gay-Lussac is the only chemist who compared (in 1821) the action of a small number of salts, by determining which of them are sufficient, if taken up by linen to the amount of 10 per cent., and, finding no salt to answer in this proportion, by further determining which are sufficient, if taken up to the amount of 20 per cent.

The annexed Table, comparing a considerable number of salts, including all those which seemed to be of practical interest, and some others on account of chemical analogies, has been composed by employing another method; viz. by determining the smallest proportions of different salts required in solution, if this solution shall have the desired effect. This method brings out some remarkable facts, and allows of the following general conclusions:—

Every inorganic salt, if applied in solution to fabrics, diminishes their inflammability by absorbing heat and excluding the free access of the air. Even those salts, which, like chloride of sodium, proved not to protect the fibre, would most probably do so if sufficiently concentrated solutions could be obtained.

More active than other salts are those which are easily fusible (such as borax), or partially or entirely volatile, thereby rarefying the inflammable hydrocarbons (such as certain salts of ammonia and as the carbonates of soda), or those, which owing to their peculiar physical constitution, firmly envelope the fibre, such as the tungstate of soda. It will be seen that some salts frequently recommended have no practical value; that alum, for instance, is required in a proportion that injures the appearance of the fabrics; that carbonate of ammonia is too little soluble, and, like sal-ammonia, too volatile; and that borax, owing to its boracic acid, destroys the fabric at higher than ordinary temperatures. A solution of only one per cent. of borate of ammonia has the same effect, and boracic acid alone cannot protect the fibre.

The experiments referred to were not confined to the laboratory, but repeated under different circumstances in Her Majesty's laundry at Richmond, and at the Finishing Works of Mr. W. Crum, and of Mr. Cochran of Glasgow. It was found thereby that only the following five salts and mixtures allow of a practical application:—the phos-

Table showing the smallest per-centage of Salts required in solution for rendering Muslin non-inflammable,—A of crystallized, B of anhydrous salts; twelve inches square of the muslin employed weighing 33·4 grains.

Name of the Salts.	Formula of the Salts.	A.	B.	Remarks.
1. Caustic soda............	$NaO\ HO$	8	6·2	Destroy the fabric.
2. Carbonate of soda......	$NaO\ CO_2\ 10HO$	27·7	10·0	
3. Carbonate of potash...	$KO\ CO_2\ 2HO$	12·7	10·0	
4. Bicarbonate of soda...	$NaO_2\ CO_2\ HO$	6	5·2	Not efficacious enough.
5. Borax	$NaO\ 2BO_3\ 10HO$	25	13·2	Destroys the fabric above 212° F.
6. Silicate of soda.........	$2NaO\ 3SiO_3$	......	15·5	Makes the fabric rough.
7. Phosphate of soda.....	$2NaO\ HO\ PO_5\ 24aq$	80	30·0	Not efficacious enough.
7*a*. Idem.....................	$2NaO\ HO_5\ PO_5\ 14aq$	60	......	
8. Sulphate of soda.......	$NaO\ SO_3\ 10HO$	......	......	A concentrated 72 per cent. solution is insufficient.
9. Bisulphate of soda.....	$NaO\ 2SO_3\ HO$	20	15·0	Destroy the fabric.
10. Sulphite of soda	$NaO\ SO_2\ 10HO$	25	10·3	
11. Tungstate of soda......	$NaO\ WO_3\ 2HO$	20	18	Very useful, the only salt that allows of ironing the fabric.
12. Stannate of soda.......	$NaO\ Sn\ O_2\ 3HO$	20	15·1	Deliquescent and alkaline.
13. Chloride of sodium	$NaCl$	......	......	Concentrated solutions are insufficient.
14. Chloride of potassium	KCl			
15. Cyanide of potassium	KCy	......	10	Not applicable for obvious reasons.
16. Sesquicarbonate of ammonia...........	....	......	......	A concentrated solution is insufficient. The salt is too volatile.
17. Oxalate of ammonia...	....	......	......	Increases the flame.
18. Biborate of ammonia..	$NH_4O, 2BO_3\ 4HO$	5	3·7	Destroys the fabric above 212° F.
19. Phosphate of ammonia	$2NH_4\ OHO\ PO_5$	10	9·3	Useful.
20. Phosphate of ammonia and soda.....	$NaO\ NH_4\ OHO\ PO_5\ 8HO$	15	8·6	Useful.
21. Sulphate of ammonia..	$NH_4\ OSO_3\ HO$	7	6·2	Useful, and recommended on account of its low price.
22. Sulphite of ammonia..	$NH_4\ OSO_2\ HO$	10	9·0	Destroys the fabric.
23. Chloride of ammonium	$NH_4\ Cl$	......	25·0	Too volatile.
24. Iodide of ammonium...	$NH_4\ I$	......	5·0	Excluded from application from the fact of their high price.
25. Bromide of ammonium	$NH_4\ Br$	......	5·0	
26. Urea	$C_2\ H_4\ N_2\ O_2$	......	40	
27 Thouret's compound...	$3(NH_4Cl)$ $2(2NH_4\ OHO\ PO_5)$	12	......	Useful.
28. Chloride of barium	$Ba\ Cl$	......	50·0	Not efficacious enough.
29. Chloride of calcium ...	$Ca\ Cl$	20	10·0	Deliquescent.
30. Sulphate of magnesia..	$MgO\ SO_3\ 7HO$	50	24·5	Not efficacious enough.
31. Sulphate of alumina...	$Al_2\ O_3\ 3SO_3\ 18HO$	15	7·1	Injurious to the fabric.
32. Potash-alum............	$KO\ SO_3\ Al_2\ O_3\ 3SO_3\ 24HO$	33	18·0	Not efficacious enough.
33. Ammonia-alum.........	$NH_4\ SO_3\ Al_2O_3\ 3SO_3\ 24HO$	25	13·0	
34. Sulphate of iron	$FeO\ SO_3\ 7HO$	53	28·8	Not efficacious enough.
35. Sulphate of copper	$CuO\ SO_3\ 7HO$	20	11·2	Poisonous.
36. Sulphate of zinc	$ZnO\ SO_3\ 7HO$	20	11·2	
37. Chloride of zinc	$ZnCl\ HO$	8	5·8	Deliquescent.
38. Protochloride of tin...	$SnCl\ HO$	5	4·6	Deliquescent.
39. Protochloride of tin and ammonia........	$SnCl\ NH_4\ Cl\ HO$	5	4·7	Acquires a yellow colour if exposed to the air.
40. Pink salt................	$Sn\ Cl_2\ NH_4\ Cl$	......	7	Destroys the fabric above 212° F.

phate of ammonia, the double salt of the same with phosphate of soda, the mixture of the same with sal-ammonia, the sulphate of ammonia, and the tungstate of soda. The sulphate of ammonia is cheaper, and required in a smaller proportion than the other salts. According to Mr. Walter Crum, it gives a good finish to the fabrics; and as madder-purple is the only colour which is slightly injured by this salt, it may be employed in the manufacturing processes of almost all light fabrics. But in laundries tungstate of soda alone can be used, because this salt alone allows of passing the iron smoothly over the fabric without injuring it. Tungstate of soda is a cheap salt at present, because it is manufactured for the precipitation of tungstate of lead, which is now in frequent use instead of white lead; and although a solution of 20 per cent. of tungstate of soda is required, this represents only a small volume of the salt. It has proved very useful, and is now in constant use in Her Majesty's laundry. A solution of it cannot be preserved without adding a small proportion of phosphoric acid, or of phosphate of soda, to prevent the formation of a bitungstate of little solubility.

Besides the experiments hitherto referred to, others were necessary, in order to ascertain the possibility of permanently fixing antiflammable substances into the fibre so as to prevent them from being removed by water. The following substances were tried without success:—by Morin, tannate of zinc mixed with glue; by others, sulphate of lime; by the authors of this communication, sulphate of baryta, the silicates of alkaline earths and of earths, aluminate of zinc, oxychloride of antimony, arseniate of tin, and the stannates of lime and of zinc. It was found possible, however, to fix either of the following substances:—the borate and the phosphate of tin, stannate of tin and hydrated protoxide of tin. But all these substances give a yellowish tinge to the fabrics, and are only applicable to coarse materials, such as canvas and sailcloth. The protoxide of tin is precipitated from a solution of two parts of protochloride of tin in one part of water by concentrated carbonate of soda. Care must be taken to agitate the fabric in the latter solution, in order not to fix anhydrous protoxide, which was found to be formed in all cases where a concentrated solution of protochloride of tin was mixed with an excess of concentrated carbonate of soda. It gets transformed into the hydrate by boiling it with protochloride of tin. A piece of sailcloth prepared with it is undergoing practical tests by command of the Storekeeper-General of the Navy.

On Combinations of Earthy Phosphates with Alkalies. *By* Professor Voelcker, *Ph.D., F.C.S.*

Account of Experiments on the Equivalent of Bromine. *By* W. Wallace, *Ph.D., F.C.S.*

The author employed the bromide of arsenic, a compound which is readily obtained in a perfectly pure state by distillation and crystallization. The mean number obtained was 79·74, which does not differ materially from the equivalent of Marignac.

On Proposed Improvements in the Manufacture of Kelp. *By* W. Wallace, *Ph.D., F.C.S.*

Great loss of iodine occurs in the present mode of fabrication, and certain sulphur compounds are produced which are highly objectionable and cause a great waste of oil of vitriol in their neutralization or decomposition. Dr. Wallace described various suggestions by which a much greater quantity of kelp might be prepared in the Hebrides, and the quality very much improved.

Mr. Napier's *New Process of Etching Glass in relief by Hydrofluoric Acid.* *Communicated by* Professor G. Wilson.

This process, devised and patented by Mr. Napier, is exceedingly ingenious, and for many purposes of art highly satisfactory. A wood-cut with a device printed in the usual way in printers' ink, is attached by a paste of starch to the surface of glass intended to be etched, and the whole is allowed to dry.

The prepared glass is then plunged into dilute hydrofluoric acid, left there for a short time; then washed and the paper cleaned off.

During the brief immersion the acid has penetrated the paper, including the starch, wherever the former was free from ink-marks, and has corroded or dissolved away the glass over all the points or spaces corresponding to the white paper; whilst the ink-lines making up the design have acted like a protective varnish, defending the glass below them from corrosion.

The peculiarity of the process lies in allowing the paper, as well as the ink, to remain in contact with the glass during its immersion in the acid. It is impossible to etch deeply with hydrofluoric acid, in consequence of the acid acting laterally as well as vertically as soon as it has removed the superficial layer. The process, however, yields results of great beauty, both with colourless glass, and with that *flushed*, that is, covered by a thin plate of coloured glass. Copies of wood-cuts or engravings may thus be produced in various colours; and for windows and lamp shades, as well as for decanters, toilet bottles, drinking vessels and the like, the method is readily and cheaply applicable.

Other applications will occur to every one who masters the principle of this process. Wood-cuts are only preferable to other forms of engraving as giving broader lines, and yielding in printing ink an admirable protective varnish.

The essential part of the process is the retention of the paper to the proof and etching.

On some of the Stages which led to the Invention of the Modern Air-pump. By Professor George Wilson.

The author began by stating that he had long ago proposed to himself the task of illustrating the special service which the '*Instrument*' rendered to physical science, as distinguished from the '*Idea*' or thought which guided the physicist in devising and using the instrument, and the effect of individual peculiarity or idiosyncrasy in affecting the interpretation of those phenomena and laws which the idea and the instrument together brought to light.

In the history of every science we recognize the prevalence at particular periods, of a more or less comprehensive Thought, Idea, Hypothesis or Theory, which determines the direction of inquiry during that epoch. Such, for example, in astronomy was the doctrine that the earth goes round the sun; such in chemistry the doctrine that combustion results from the union of unlike chemical substances.

These and similar ideas, however, even when most true, never reach mankind as pure truth, the *lumen siccum* of the Divine Mind, but are always more or less modified, coloured, or obscured by the idiosyncrasy of the human expositor who first gives them utterance. The antecedents, accordingly, of such men as Copernicus, Galileo and Lavoisier, the quality of their intellects and moral faculties, their education and training, the fears and prejudices or hindrances under which they wrought, and much else must be studied, before we can rightly estimate their influence over the progress of science.

Further, in the case of the physical sciences, and especially the experimental ones, a third and notable element, affecting their progress, appears in the character of the instruments by which the phenomena they are concerned with, are observed, tested, analysed, and registered. Thus Galileo's *telescope* furnished every man with ocular demonstration of the truth of the Copernican views; and Lavoisier's *balance* for ever extinguished the *ignis fatuus* of phlogiston.

A comprehensive history of any physical science must include all three elements: viz. 1. the dominant idea of a given epoch, which, in so far as it was true, was the recognition of an actual law of nature or thought of God's; 2. the human expositors of this idea, who in converting it into a formal doctrine, always more or less modified it, and often in consequence retarded or misdirected the progress of knowledge for centuries; 3. the instrument realizing or applying the idea or doctrine; in some cases justifying a hypothesis, in others pointing to a theory,—in all bringing physical phenomena much more within reach of the observer.

The author thought that the historians of physics had too little regarded the importance of the last element of influence. The telescope, the microscope, the barometer, the thermometer, the air-pump, the electrical machine, the galvanic battery, the electro-magnet, the photographic camera, and many other instruments, has each added a new kingdom to the map of science, and a new chapter to its history.

In communications addressed to different learned bodies, the author has referred to several of these instruments; the object of his present paper is to indicate some important points in the early history of the air-pump.

In relation to instruments intended to produce a vacuum, we may conveniently regard vacua as of four kinds:—

1. The suction or pump-vacuum.
2. The thermic (including the steam-) vacuum.
3. The Torricellian or barometer-vacuum.
4. The chemical vacuum.

The instrument for producing the first is, *par excellence*, the air-pump, the philosopher's chief vacuum-producer, although for some purposes, as the recent researches on the electric discharge have shown us, both the Torricellian and the chemical vacuum are preferable to the pump-vacuum.

The instruments for producing the second or thermic vacuum, as represented for the mechanician by the condenser of the steam-engine, and for the industrial chemist by the vacuum-pan and vacuum-still, constitute the practician's vacuum-producer. Now these two instruments, the philosopher's air-pump and the practician's steam-condenser, may be shown to have come down to us by different lines from prehistoric times.

Suction Vacuum.—The simplest and earliest suction vacuum-producer was the mouth of a suckling, and passing over other mammals, we may be content to begin with the human infant. The mouth, including the lips, cheeks and tongue, constitutes an exhausting apparatus more perfect than any artificial contrivance. What the infant does instinctively, the adult continues by an almost unconscious effort of will, occasionally to perform. To suck a bleeding wound, or poisoned bite, seems natural even to highly civilized man, and is practised by all barbaric nations. From this there is but one step to interposing, between the mouth and the wound, a tube or funnel, especially when the mouth of one individual sucks a bleeding or poisoned surface in the body of another. This step was taken by the ancient cupper, who after scarifying the skin of his patient, employed the extremity of a bullock's horn pierced at the tip and left open at the base. When the latter was applied to the bleeding orifices, and suction made through the hollow tip, the blood rose into the cone, and it was easy to close the upper aperture by the tongue, the finger, a little soft wax, a piece of wet membrane, or a leather valve, as in truth was variously done.

Such a cupping horn is alluded to by Hippocrates as an instrument which was ancient in his days. The later Greek and Roman physicians describe it more minutely. Three cupping horns have been found in the tombs of Saccara, at Memphis, and have been described by Dr. Abbot, in whose museum, formerly at Cairo, they were deposited. Of their genuineness and antiquity there appears, according to Sir Gardner Wilkinson, who has seen one of them and has favoured the author with his opinion, to be no doubt. Similar horns provided with a leather valve or tongue at the upper aperture, are still, according to this high authority, in familiar use among the modern Egyptians. In Abyssinia Parkyns has seen the horn used for cupping. Mungo Park gives a similar account. Dr. Brown, of Her Majesty's Indian Service, informs the author that he has seen the cupping horn used by the natives of the Punjaub. Dr. Cannon, formerly Civil Surgeon at Simla, adds that he has witnessed a Cashmeer Hakeem cup most skilfully with the tip of the mountain ram's horn. When a party of Red Indians of the Ioway tribe were in Edinburgh some years ago, Professor Simpson, on visiting them on one occasion, found one of the men cupping another with part of a cow's horn. Lastly, the author exhibited a cupping horn still in use among the Shetlanders. He was indebted for it to Prof. Simpson, who had received it from the Rev. Mr. Ingram, parish clergyman of Unst. It is styled by the natives a "blude horn;" the operation of cupping with it is named "horning."

It thus appeared that a suction vacuum-producer, or mouth air-pump, has been in use as a cupping instrument for some thousand years, its origin being lost in remote antiquity; and also that it has been and is in use among nations widely separated from each other. If we suppose these peoples to have acquired the practice from one common source, the extreme antiquity of the practice must be conceded. If, on the other hand, as is more likely, several at least of those nations devised it for themselves, then the facility with which men construct a vacuum-producer is rendered apparent. Without endeavouring to establish precise dates, we may safely affirm that a mouth air-pump has been known for more than twenty centuries in various regions of the globe.

That such an instrument should lead directly to the construction of an air-pump seems at first sight in the highest degree probable; for if we look at Otto v. Guericke's first modern air-pump (1654), or Boyle and Hooke's first English one (1659), we seem to see a copy in all essentials of the suction horn: the horn is replaced by a glass vessel, the mouth by a metal cylinder and piston directly communicating with the glass. But history does not confirm this supposition. Had it been well-founded, we should not have had to wait for much more than a thousand years before we had an air-pump; neither should we find that instrument totally unknown to the great majority of those nations who were quite familiar with the cupping horn.

It appears from the writings of Guericke, Boyle and their contemporaries, that it was the Torricellian tube that led them to construct their air-pumps. We must in truth intercalate the barometer between the suction-horn and the air-pump; for although the last seems but a copy in glass and metal of the second, it was not in reality so. Galileo in 1600 explained the action of a water-pump and suggested the Torricellian experiment. Torricelli tried it in 1644; and men at length believed in the possibility of producing a vacuum, a truth which the cupping horn had not taught them.

At length, after ten years' endeavour, not without success, to make a large bulbed barometer serve the purposes which the air-pump now fulfils, Guericke took courage to attempt a pump. But he did not at first endeavour to pump out air, as he certainly would have done, had he modeled his instrument on the suction-horn. On the other hand, he filled a barrel or globe with water, and pumped out that. In short, his first air-pump was a Torricellian tube, from which the liquid, instead of being withdrawn by its weight, compared with that of the air, was exhausted by a syringe. By and by, struck with the elasticity of the air and its continual expansion under diminished pressure, he dismissed liquids, and acted with his pump directly on the air in a shut vessel. Till, however, the Torricellian experiment taught him two truths—the one that a vacuum is possible, the other that air is elastic—the air-pump remained an unrealized possibility. The barometer, accordingly, and not the cupping horn, was the genetic precursor of the modern air-pump, a fact which has not apparently received from the historians of science the attention it deserves. The later stages in the air-pump—involving the introduction by Hooke and Boyle (1667) of the separate "*plate*" on which bell-jars could stand, the employment of two barrels by Papin (1676), with a *stirrup* or *treddle* arrangement for working the pistons by the feet, and the replacement of this curious device by the familiar rack and pinion to move the two pistons, by Hauksbee (1704)—was not enlarged upon, as it had been treated by the author elsewhere.

Thermic Vacuum.—The condensing chamber of a Watt's steam-engine, or the vacuum pan of a sugar refiner, are generally regarded as very modern inventions. These powerful pneumatic evacuators, however, stand in the same relation of descent to the cupping glass, in which a vacuum is produced by the action of a flame, as the scientific air-pump does to the suction cupping horn. The former, which may be called the *flame-cup*, was as familiar to Hippocrates as the suction horn, and is equally referred to, as in his day an ancient instrument. Later Greek and Roman medical writers, such as Oribasius, Paulus Ægineta and Celsus, describe the flame-cups as made chiefly of bronze, sometimes of glass, and occasionally of earthenware. In the ruins of Herculaneum and Pompeii examples have been found, which are now in the Museo Borbonico at Naples, and have been figured by Vulpes. Of whatever material these instruments were anciently constructed, they were similarly named, the Greek term for a cupping glass being *σίκυα* (*sikua*), and the Latin *cucurbitula*, each alike signifying a *small gourd*. Lexicographers refer this unexpected title, solely to the resemblance *in form* of the cupping glass to a gourd. The author believes this to be a mistake, in consequence, mainly, of finding that an actual gourd has been used as a flame-cup by the natives of Africa on the Old Calabar river, as well as by negroes from other African districts, from time immemorial. In illustration he showed three cupping gourds brought from Old Calabar by A. Hewan, Esq., Surgeon to the United Presbyterian Mission there. This gentleman has frequently seen the gourd employed to let blood by the native women, who scarify the skin with a razor, and then burn a piece of cotton within the gourd till the air is sufficiently rarefied, when the light is withdrawn and the vegetable cup applied. When it is further remembered that the ancient cupping vessels were of very various shapes and sizes, and that the terms under notice were applied to the horn-*cone* as well as to the bronze *egg-shaped* cyathus, it is difficult to believe that *sikua* and *cucurbitula* refer chiefly to the *form* of the ancient cupping instrument. It seems more probable that the words in question are memorials of the fact that a hollow gourd was itself the earliest flame-cup employed by primitive races, from whom the civilized nations of antiquity inherited the name and practice. The curious fact may be added, that both the African negroes and the South American Indians are in the occasional habit of employing the neck of a bottle gourd, or the body of a small oval one, with a wide aperture below and a narrow one above, as a suction-tube, just as nations in possession of cattle use the suction-horn. If this practice prevailed in ancient times and in classical regions, then the words *sikua* and *cucurbitula* were equally applicable to a suction-horn and a flame-cup, and the shape of either goes for almost nothing.

This, however, is an episode; the only point of special interest to the present question is the antiquity of the flame-cup, and of this there is no doubt. It was so well known to the Greeks of all ranks, that Aristophanes refers to it in one of his plays, using the term *κύαθοι* (cyathoi), or cups. Cupping must have been as familiar to his audience as *leeching* to modern play-goers, and the word *cup* excludes the idea of a suction instrument. In round numbers we may date this allusion 500 B.C., and the practice alluded to was then a very ancient one. It is impossible, however, to identify a cup used for blood-letting, in the way we can identify so unique an instrument as a cupping horn. Among the vessels found in Pharaonic Egyptian tombs, and in the ruins of ancient cities, are many resembling cupping vessels, and some of which may have been such. However, that learned archæologist, Mr. Birch of the British Museum, could not refer the author to any evidence derived from instruments, inscriptions, or drawings illustrating the use of the flame-cup among the ancient Egyptians or other civilized nations of antiquity. It is enough nevertheless to know that for centuries before Hippocrates, Socrates, and Aristophanes flourished, a method of applying heat to produce a vacuum in a vessel previously full of air, was widely known and practised in the ancient world, and that it now prevails among barbaric nations, who can give no account of its origin.

Between this flame-cup and the steam-vacuum it is impossible not to see a close analogy. In both we rarefy an elastic fluid by heat, and then condense it by cold; the great difference being that in the one case we employ a gas which cannot be liquefied, and in the other a vapour easily condensable into a liquid. In the cupping vessel, however, we have always liquefiable water-vapour and carbonic acid produced, and from the steam-vacuum we cannot exclude incondensable air. There is thus rather a difference in degree than in kind between the two instruments. Nevertheless historically the one is not the other grown perfect, or the descendant of the other. Just as the *barometer* comes between the suction-horn and the air-pump, and interprets the former into the latter, so the *thermometer* comes after the flame-cup and translates it into the steam-vacuum.

We find a barren interval till we reach the 16th century, and the progress in applying a thermic vacuum to the production of motion through the steam-engine is exceedingly slow, till the thermometer has been graduated and rendered a trustworthy measurer of the intensity and quantity of heat. The discovery of the laws of latent heat, and of much else, soon leads to the construction of the condensing steam-engine, and by and by to that of the vacuum-pan and vacuum-still. Neither of them recalls its prototype the flame-cup, yet the crashing in of the sides of a collapsing boiler is but a repetition on a large scale of the phenomenon exhibited by the sucking in of the skin by a cupping glass as it cools.

The cupping instrument is thus in a twofold way the precursor of the modern vacuum-producer: as the cupping horn, it leads through the barometer to the air-pump; as the cupping gourd, it leads through the thermometer to the vacuum-still. The beginnings of both instruments are lost in prehistoric times, and in the present state of our knowledge we are safest to regard them as equally ancient.

The chemical vacuum produced by filling a vessel with a gas which can afterwards be reduced to a solid form by chemical combination with another substance, is one of the most perfect attainable vacua, but its consideration is postponed till a future opportunity.

GEOLOGY.

Introductory Address by the President, Sir C. Lyell.

On the Occurrence of Works of Human Art in Post-pliocene Deposits. By Sir Charles Lyell, *LL.D., D.C.L., F.R.S.*

No subject has lately excited more curiosity and general interest among geologists and the public than the question of the antiquity of the human race; whether or no we have sufficient evidence to prove the former co-existence of man with certain extinct mammalia, in caves or in the superficial deposits commonly called drift or "diluvium." For the last quarter of a century, the occasional occurrence, in various parts of Europe, of the bones of man or the works of his hands, in cave-breccias and stalactites associated with the remains of the extinct hyæna, bear, elephant, or rhinoceros, has given rise to a suspicion that the date of man must be carried further back than we had heretofore imagined. On the other hand, extreme reluctance was naturally felt on the part of scientific reasoners to admit the validity of such evidence, seeing that so many caves have been inhabited by a succession of tenants, and have been selected by man, as a place not only of domicile, but of sepulture, while some caves have also served as the channels through which the waters of flooded rivers have flowed, so that the remains of living beings which have peopled the district at more than one era may have subsequently been mingled in such caverns and confounded together in one and the same deposit. The facts, however, recently brought to light during the systematic investigation, as reported on by Falconer, of the Brixham Cave, must, I think, have prepared you to admit that scepticism in regard to the cave-evidence in favour of the antiquity of man had previously been pushed to an extreme. To escape from what I now consider was a legitimate deduction from the facts already accumulated, we were obliged to resort to hypotheses requiring great changes in the relative levels and drainage of valleys, and, in short, the whole physical geography of the respective regions where the caves are situated—changes that would alone imply a remote antiquity for the human fossil remains, and make it probable that man was old enough to have co-existed, at least, with the Siberian mammoth.

But, in the course of the last fifteen years, another class of proofs have been advanced, in France, in confirmation of man's antiquity, into two of which I have personally examined in the course of the present summer, and to which I shall now briefly advert. First, so long ago as the year 1844, M. Aymard, an eminent palæontologist and antiquary, published an account of the discovery in the volcanic district of Central France, of portions of two human skeletons (the skulls, teeth, and bones), imbedded in a volcanic breccia, found in the mountain of Denise, in the environs of Le Puy en Velay, a breccia anterior in date to one, at least, of the latest eruptions of that volcanic mountain. On the opposite side of the same hill, the remains of a large number of mammalia, most of them of extinct species, have been detected in tufaceous strata, believed, and I think correctly, to be of the same age. The authenticity of the human fossils was from the first disputed by several geologists, but admitted by the majority of those who visited Le Puy and saw, with their own eyes, the original specimen now in the museum of that town. Among others, M. Pictet, so well known to you by his excellent work on Palæontology, declared after his visit to the spot his adhesion to the opinions previously expressed by Aymard. My friend, Mr. Scrope, in the second edition of his 'Volcanoes of Central France,' lately published, also adopted the same conclusion, although, after accompanying me this year to Le Puy, he has seen reason to modify his views. The result of our joint examination,—a result which, I believe, essentially coincides with that arrived at by MM. Hébert and Lartet, (names well known to science,) who have also this year gone into this inquiry on the spot,—may thus be stated. We are by no means prepared to maintain that the specimen in the museum at Le Puy (which unfortunately was never seen *in situ* by any scientific observer) is a fabrication. On the contrary, we incline to believe that the human fossils in this and some other specimens from the same hill, were really imbedded by natural causes in their present matrix. But the rock in which they are entombed consists of two parts, one of which is a compact, and for the most part thinly laminated stone, into which none of the human bones penetrate; the other containing the bones is a lighter and much more porous stone, without lamination, to which we could find nothing similar in the mountain of Denise, although both M. Hébert and I made several excavations on the alleged site of the fossils. M. Hébert therefore suggested to me that this more porous stone, which resembles in colour and mineral composition, though not in structure, parts of the genuine old breccia of Denise, may be made up of the older rock broken up and afterwards re-deposited, or as the French say, *remanié*, and therefore, of much newer date, an hypothesis which well deserves consideration; but I feel that we are at present so ignorant of the precise circumstances and position under which these celebrated human fossils were found, that I ought not to waste time in speculating on their probable mode of interment, but simply state that, in my opinion, they afford no demonstration of man having witnessed the last volcanic eruptions of Central France. The skulls, according to the judgment of the most competent osteologists who have yet seen them, do not seem to depart in a marked manner from the modern European, or Caucasian type; and the human bones are in a fresher state than those of the *Elephas meridionalis* and other quadrupeds found in any breccia of Denise which can be referred to the period even of the latest volcanic eruptions.

But while I have thus failed to obtain satisfactory evidence in favour of the remote origin assigned to the human fossils of Le Puy, I am fully prepared to corroborate the conclusions which have been recently laid before the Royal Society by Mr. Prestwich, in regard to the age of the flint implements associated in undisturbed gravel, in the north of France, with the bones of elephants, at Abbeville and Amiens. These were first noticed at Abbeville, and their true geological position assigned to them by M. Boucher de Perthes, in 1847, in his 'Antiquités Celtiques,' while those of Amiens were afterwards described in 1854, by the late Dr. Rigollot. For a clear statement of the facts, I may refer you to the abstract of Mr. Prestwich's Memoir in the Proceedings of the Royal Society for 1859, and have only to add that I have myself obtained abundance of flint implements (some of which are laid upon the table) during a short visit to Amiens and Abbeville. Two of the worked flints of Amiens were discovered in the gravel-pits of St.-Acheul—one at the depth of 10, and the other of 17 feet below the surface, at the time of my visit; and M. Georges Pouchet, of Rouen, author of a work on the Races of Man, who has since visited the spot, has extracted with his own hands one of these implements, as Messrs. Prestwich and Flower had done before him. The stratified gravel resting immediately on the chalk in which these rudely fashioned instruments are buried, belongs to the post-pliocene period, all the fresh-water and land shells which accompany them being of existing species. The great number of the fossil instruments which have been likened to hatchets, spear-heads, and wedges is truly wonderful. More than a thousand of them have already been met with in the last ten years, in the valley of the Somme, in an area 15 miles in length. I infer that a tribe of savages, to whom the use of iron was unknown, made a long sojourn in this region; and I am reminded of a large Indian mound, which I saw in St. Simon's Island, in Georgia—a mound 10 acres in area, and having an average height of 5 feet, chiefly composed of cast-away oyster shells, throughout which arrow-heads, stone-axes, and Indian pottery are dispersed. If the neighbouring river, the Alatamaha, or the sea which is at hand, should invade, sweep away, and stratify the contents of this mound, it might produce a very analogous accumulation of human implements, unmixed perhaps with human bones.

Although the accompanying shells are of living species, I believe the antiquity of the Abbeville and Amiens flint instruments to be great indeed if compared to the times of history or tradition. I consider the gravel to be of fluviatile origin; but I could detect nothing in the structure of its several parts indicating cataclysmal action, nothing that might not be due to such river-floods as we have witnessed in Scotland during the last half-century. It must have required a long period for the wearing down of the chalk which supplied the broken flints for the formation of so much gravel at various heights, sometimes 100 feet above the present level of the Somme,—for the deposition of fine sediment including entire shells, both terrestrial and aquatic, and also for the denudation which the entire mass of stratified drift has undergone, portions having been swept away, so that what remains of it often terminates abruptly in old river-cliffs, besides being covered by a newer unstratified drift. To explain these changes, I should infer considerable oscillations in the level of the land in that part of France—slow movements of upheaval and subsidence, deranging but not wholly displacing the course of the ancient rivers. Lastly, the disappearance of the elephant, rhinoceros, and other genera of quadrupeds now foreign to Europe, implies, in like manner, a vast lapse of ages, separating the era in which the fossil implements were framed and that of the invasion of Gaul by the Romans.

Among the problems of high theoretical interest which the recent progress of Geology and Natural History has brought into notice, no one is more prominent, and at the same time more obscure, than that relating to the origin of species. On this difficult and mysterious subject a work will very shortly appear, by Mr. Charles Darwin, the result of twenty years of observation and experiments in Zoology, Botany, and Geology, by which he has been led to the conclusion, that those powers of nature which give rise to races and permanent varieties in animals and plants, are the same as those which, in much longer periods, produce species, and, in a still longer series of ages, give rise to differences of generic rank. He appears to me to have succeeded, by his investigations and reasonings, in throwing a flood of light on many classes of phenomena connected with the affinities, geographical distribution, and geological succession of organic beings, for which no other hypothesis has been able, or has even attempted, to account.

Among the communications sent in to this Section, I have received one from Dr. Dawson, of Montreal, confirming the discovery which he and I formerly announced, of a land shell, or pupa, in the coal formation of Nova Scotia. When we contemplate the vast series of formations intervening between the tertiary and carboniferous strata, all destitute of air-breathing Mollusca, at least of the terrestrial class, such a discovery affords an important illustration of the extreme defectiveness of our geological records. It has always appeared to me that the advocates of progressive development have too much overlooked the imperfection of these records, and that, consequently, a large part of the generalizations in which they have indulged in regard to the first appearance of the different classes of animals, especially of air-breathers, will have to be modified or abandoned. Nevertheless, that the doctrine of progressive development may contain in it the germs of a true theory, I am far from denying. The consideration of this question will come before you when the age of the White Sandstone of Elgin is discussed—a rock hitherto referred to the Old Red, or Devonian formation, but now ascertained to contain several reptilian forms, of so high an organization as to raise a doubt in the minds of many geologists whether so old a place in the series can correctly be assigned to it.

On Human Remains in Superficial Drift. By the Rev. Dr. Anderson.

The author gave a view of the alleged cases in connexion with the discovery of human remains in the superficial drifts, alluvial detritus, and such diluvial accumulations as are of an ancient or pre-historic origin. Undoubted cases existed of human remains enclosed in hard compact concretionary rocks, buried deep in the silts of rivers, and high up in caverns, associated with the bones of extinct carnivora now only existing in southern latitudes. One is startled at the idea of a North Briton inhabiting the same cave with a lion, mammoth, or a huge bear, and all apparently contemporaneous occupants, according to their species, of the British Isles. As to the instances occurring in beds of lakes, rivers, and seas, and which have become mineralized, he contended that a few years, or even months, often sufficed for the formation of a compact durable mass of calcareous and siliceous rock, in which human bones, skeletons, pottery, coins, and implements were imbedded.

He referred to a case betwixt Aberdour and Burntisland, in Fife, which he examined a few weeks ago, where an incrustation was now forming of great depth, and in which are imbedded land shells, branches of trees, and where on the face of the incrusted cliff, twigs of the living trees are becoming entangled in the calcareous breccia. Several raised beaches occur on the shores of Fifeshire, of considerable elevation, and some of them strewed over with shells of the pleistocene age. They lie, some of them, in the close vicinity and direct line of the Aberdour breccia. Through the agency of springs, which are copious and numerous in the district, and by many other causes, the shelly materials of the raised beaches may be brought in contact with the petrifying incrustations, mixed up with the land-shells and mollusks of the day, which are sufficiently abundant around; and, when removed to a distance from the combined formative processes on the spot, what room is here for speculations and hypotheses to puzzle and confound the curious inquirer into the history of the aggregated mass! The *old*, the *new*, and the *living* are all in juxtaposition—all ready to be confounded in a matrix of yesterday.

He next quoted the case of a cannon-ball—a thirty-two pounder—lately presented to him by a fellow townsman, deeply incrusted with ferruginous mud, and completely indurated, which was raised on an anchor in the harbour of Copenhagen; and, he doubted not, an identical bullet of our naval attack of fifty years ago. The flints of Amiens and Abbeville, the remains in the caverns of Torquay, and those in Sicily, the flint weapons in veined limestone in Cantire, and the arrow-heads with elephant remains in Suffolk, were then successively brought under review in the paper,—the solution of all these given by the author being that, from the action of petrifying springs, the subsidence of tracts of country, the falling in of the roofs of caverns, the undermining of cliffs and headlands, the superficial soil is incrusted or buried beneath the strata on which it was originally superimposed.

The case of the Nile piece of pottery, brought before the meeting at Leeds last year by Mr. Horne, was next adverted to. The answer to the assumption of its vast antiquity is found in the fact, that the track of the Nile through the whole of its course in Lower Egypt, has been subject to such successive mutations of level as to render all comparisons between the present and the past of the yearly increment and amount of silt deposits over the bed of the river utterly useless. It is clearly established that, in the course of the last 3000 years, the land around Suez has risen 8 or 10 feet; and it is no less warrantably established, that the whole Lower Delta and the entire shores east and west of Cairo and Alexandria have been repeatedly subjected to such depressions and upheavals as to dry up lakes, and to change the channel of the Nile itself. Four thousand years ago, up to the borders of the Theban provinces, 200 miles inland, was an estuary or marsh, where the gradients and speed of the river would be directly affected by the rise or fall of the basin to the northward, the existing delta, from Cairo south, becoming ultimately dry land, or marsh, or lake. When the Egyptian monarchy was founded by Menes about 4000 years from the present time, the land of Egypt, from the Theban province *northward*, was a marsh, and from the Lake Mœris, 150 miles *southward*, all from the sea-coast at Alexandria was permanently under water. *Eastward* on the Red Sea shore, and across the Isthmus from Suez *westward* to the Mediterranean, is a raised beach of shells, corals, and gravel, the corals consisting exclusively of varieties now in existence. The bed of the Nile within the past 4000 years has therefore sunk repeatedly and risen again; and Dr. Lepsius mentions a series of monuments at Senneh in Nubia, which record the highest points reached by the inundations, fifteen of which are still available for reference, the height of them proving that the Nile rose at that period 25 feet higher than in modern times.

The position, then, of these and other registers and proofs referred to, completely establishes the theory of a succession of upheavals and depressions, and destroys all confidence in any assumed rate of increase in the mud deposits betwixt the present and the past. The flow of the river is modified by the position of its line of debouchure, and this again is dependent on the relation, for the time, betwixt the levels of the land and sea; and, finally, it follows that the Memphian monument of king Rameses stands on a foundation of silt to which no possible date can be assigned, whether of longer or shorter calculation.

He saw no evidence, in short, deducible from the superficial drifts to warrant a departure from the usually accepted date of man's very recent introduction upon the earth. We have more positive evidence that his first appearance was characterized by many proofs of high intellectual condition which our sacred beliefs attach to his origin, and that he was not primarily the ignoble creature that arrow-heads and flint-knives, and ossiferous caverns would so lamentably indicate. The mighty ruins spread over the plains and great river water-sheds of the East clearly indicate his Oriental cradle-land, when, in conjunction with the traditions of all nations in the most remote times, he dwelt in palaces, luxuriated in gardens, worshiped in temples of solemn grandeur, and reared towers and pyramids enduring as the rocks from which they were hewn. The arts and sciences and commerce accompanied the progress of his terrestrial occupation, bringing in their train the elegances, luxuries, and perfected implements of defence or attack which the highest stages of civilization imply. Races of the human stamp have perished—are perishing; and, as if it were a law of nature, where a race cannot rise and maintain itself beyond a certain standard, civilization, instead of benefiting, only leads to their more rapid extirpation from the face of the earth. Certain it was, that tribes on islands in the Pacific, which in Cook's time were enumerated by hundreds of thousands, can now be counted by their tens or twenties; and just as certain that, wherever the christianizing element accompanied, the onward progress of civilization would know no limits until the Divine principle in man should vindicate his heaven-chartered claims to universal earthly dominion.

On Dura Den Sandstone. By the Rev. Dr. Anderson, *F.G.S.*

This deposit has now yielded nine genera and eleven species of fossil organic remains, one of which belongs to the crustacean type, and the rest to the family of true fishes. Two of the genera are common to the Old Red and the Carboniferous systems, *Holoptychius* and *Diplopterus*. Three of the genera are found in the Lower and the Upper series of the Old Red, *Pterichthys* (*Pamphractus*, Ag.), *Platygnathus*, and *Diplopterus*. Three genera are common to the Middle series of Morayshire and Clashbennie, and the Upper series of Dura Den, *Dendrodus*, *Phyllolepis*, and *Diplopterus*. Two new genera belong exclusively to the Yellow Sandstone of Dura Den, *Glyptolæmus Kinnairdii* and *Phaneropleuron Andersoni*. The author referred, for a minute description of these newly-discovered fossils, to his 'Monograph of Dura Den*,' just published, which contains Professor Huxley's account and designations of them, along with his restoration and structure of the *Holoptychius Andersoni*. In dissenting from the views of Sir Philip Egerton, in his valuable memoir recently read before the Geological Society, Professor Huxley observes, "that a small triangular dorsal fin begins opposite the hinder edge of the root of the ventral fin, and is situated a little behind the middle of the body. It is separated by about the breadth of its own base from the commencement of the dorsal lobe of the caudal fin, which occupies nearly the posterior third of the whole length of the body, and attains its greatest height about the middle of its length. The caudal end of the body gradually tapers to a point, *which is not, as has been usually represented, bent upwards*, and the ventral lobe of the caudal fin, though rather shorter than the dorsal lobe, has the same depth. *The caudal fin consequently forms a very nearly symmetrical rhomboid, and is not in the ordinary sense heterocercal.* The anal fin is rather larger than the dorsal, and is separated by but a very small interval from the ventral lobe of the caudal."

The author, in conclusion, vindicated the claims of the yellow sandstone of Dura Den to be classed with the Old Red rather than with the Carboniferous superincumbent beds; in its geognostic position, mineral qualities, and fossil organisms ranking among the rocks of the great fish epoch, and not with those which contain the flora of the succeeding age of gigantic vegetables and mountain chains of shelly limestone. Not a shell or vestige of plant has anywhere been found in the whole mass of rock of Dura Den, nor in any one of the numerous quarries in the district.

On Tertiary Fossils of India. By W. H. Baily, *F.G.S., Acting Palæontologist to the Geological Survey of Ireland.*

The object of this communication was to give merely a sketch of results from the study of a large suite of fossils collected chiefly from Burmah and Tenasserim Province, by Prof. T. Oldham, Superintendent of the Geological Survey of India, the details being intended for publication in the Memoirs of the Geological Survey

* Dura Den—a Monograph of the Yellow Sandstone and its remarkable Fossil Remains, by John Anderson, DD., F.G.S. Edinb.: Thomas Constable and Co. London: Hamilton, Adams and Co.

of India. The majority of the fossils was stated to be of Eocene age, most of them having been obtained from the banks of the Irrawaddy and from Prome and its neighbourhood. Prof. Oldham also collected Nummulitic fossils from Kurrachee Salt Range of the Punjab, Mammalian remains from the Sewalik group; fish teeth and scales from Heinlat, Tenasserim, and Carboniferous fossils also from Tenasserim Province. A list of the Tertiary fossils was given, the majority belonging to Mollusca and to the following other classes:—

Articulata—Crustacea and Cirripedia.
Radiata—Annelida and Echinodermata.
Protozoa—Foraminifera.

The collection was said to contain many new and undescribed species, and to present a facies or certain amount of resemblance generically, but not specifically, with those from the Tertiary deposits of Europe; whilst, on the contrary, it was mentioned as a somewhat remarkable fact, that the further we go back in geological time, so much the greater is seen to be the resemblance between the marine fossil Faunas of distant geographical areas; for instance, the Lower Palæozoic fossils of the furthest point yet reached in Arctic explorations are many of them absolutely identical with species from that formation found in our own country, whilst those from the more modern deposits of Cretaceous and Tertiary age continue their relations more by representation of forms than identity of species; a fact confirmatory of the important observations made by the late Prof. E. Forbes on the interesting subject of the distribution of species in geological time. Allusion was made to the various Memoirs on the Palæontology of India which have from time to time appeared, principally in the Transactions and Proceedings of the Geological Society of London, by which we are made acquainted with the geological formation of a great part of that country, showing a succession of fossiliferous strata from the Upper Tertiaries, commencing with the mammalian remains of the Sewalik hills, believed to be of Miocene age, and continuing through the Nummulitic group and other Eocene beds, the Cretaceous and Oolitic series together with Lias and Trias, to the Carboniferous and Devonian or Upper Palæozoics.

On Sphenopteris Hookeri, *a new Fossil Fern from the Upper Old Red Sandstone formation at Kiltorkan Hill, in the County of Kilkenny, with some Observations upon the Fish Remains and other associated Fossils from the same locality. By* William H. Baily, *F.G.S., Acting Palæontologist to the Geological Survey of Ireland.*

The locality from which this rare fossil fern was obtained was described as being remarkably rich in organic remains, particularly in those of plants, prominent amongst which is the *Cyclopteris Hibernica*, Forbes, a magnificent fern, of which the detached fronds are so beautifully preserved, and in such an undisturbed condition, as to leave no doubt that it once grew and flourished near to the spot in which its remains are entombed, which was probably the margin of a freshwater lake; so perfect is its state of preservation, that the most minute particulars of its structure may be observed, such as the venation of the leaflets, the various stages of its organs of fructification, and other peculiarities of its history. This fossil fern was named by the late Professor Edward Forbes, and provisionally referred by him to the genus *Cyclopteris*; since then it has, with other plants from the same formation, been examined by M. Adolphe Brongniart, who, from the form and arrangement of the leaves and their flabelliform nervation, considered it rather to belong to the genus *Sphenopteris*, and more particularly to that section of the genus called *Adiantites*; at the same time he stated that he was not acquainted with any species which approached closely to it, and thought it might possibly form even a distinct genus, from its possessing isolated or intermediate leaves, springing directly from the principal rachis between the large lateral pinnæ *.

The other associated plants consist of large fluted and punctated stems, one of

* *Vide* letter from M. Adolphe Brongniart to Sir R. Griffith, Bart., in the Journal of the Royal Dublin Society, vol. vi. 1857, p. 320.

which has been described by Professor Haughton under the name of *Cyclostigma*; others have been named *Lepidodendron Griffithii* and *minutum* by M. Adolphe Brongniart: there are several additional interesting forms, and these it is intended shortly to describe in the publications of the Geological Survey of Ireland.

Of the new fern, *Sphenopteris Hookeri*, which formed the subject of this communication, two specimens only were obtained, both of which were fragmentary, although, like the other fossils from this locality, very beautifully preserved. It was described as having a slender rachis or stalk, from which, at intervals of from one to one and a half inch, diverged branches, subdivided into branchlets, the second of these branchlets rising to a height of nearly three inches from the central portion of the branch; the leaves are bipinnate, and the leaflets divided into three and four segments, each of these being again subdivided into two or three obtuse segments, broadest at their terminations and marked by two branching and forked veins. It is one of the narrow-leaved Sphenopterides, and nearly allied to *Sphenopteris linearis*, Sternberg, from the coal-measures of Bohemia and Edinburgh, but differs in several important particulars; the species is dedicated to Dr. Joseph Dalton Hooker, distinguished as an authority on both recent and fossil botany.

The Ichthyolites or fish remains found in the same quarry, at about three feet from the surface, were imbedded in a highly indurated sandstone of a coarser character than that which contained the ferns; they consisted principally of the osseous plates of ganoid fishes belonging to the Cephalaspides, the majority of them being referred to Coccosteus; there are others, however, belonging to the genera *Asterolepis, Bothriolepis,* and probably *Pterichthys.* Two detached teeth were the only remains of a dental character observed, both being conical and ridged; they appear closely to resemble M. Agassiz's figures of the larger teeth of *Bothriolepis,* a genus of the same Cœlacanth family, to which one of the plates may perhaps also belong.

To the discovery of these characteristic Old Red Sandstone fish in Ireland, great interest is attached, as a means of determining the position of strata in that country, which has been hitherto somewhat obscure. Their remains being accompanied by the magnificent fossil ferns before mentioned, and other terrestrial plants, together with the *Anodonta Jukesii,* a large bivalve shell, closely allied to the freshwater Unios of the present day, and a crustacean, *Eurypterus Scouleri,* would appear to indicate the deposit in which they are imbedded to have been of freshwater origin; and when the investigation into the history of this important assemblage of organic forms is more fully carried out, as it is intended, the results will doubtless add to our knowledge of the conditions under which these strange forms of fish and crustacea existed during the later period of the Old Red Sandstone; a formation to which, in Scotland, a classical interest has been given by the vivid descriptions of the late Hugh Miller.

Notice of a Bone Cave near Montrose.

By William Beattie, *Hon. Sec. Montrose Nat. Hist. and Antiq. Soc.*

This cave, in the parish of St. Cyrus, County of Kincardine, is situated near the mouth of the river North Esk, in that range of trap rocks extending eastward from the Northwater Bridge, on the Aberdeen road, to the cliffs of St. Cyrus—the base of the cave being at present 10 or 12 feet above the level of the sea, from which it is distant nearly a mile, and from the nearest point of the river North Esk about half as much. The entrance to the cave is through a hard compact rock of trap, and measures 12 feet wide by 5 high. On entering, the cavity suddenly widens out to the breadth of 20 feet, with a height varying from 20 to 30, the whole having been crammed to the roof with a deposit of fine dark loamy soil, containing a variety of organic remains. It was evident that the work of excavation had been carried on for some time, and we discovered evidences that, to the farmer Mr. Walker, the cave had proved a regular bed of guano, fertilizing his soil and improving his crops. In his operations, however, many of the fossil remains had been allowed to be taken away; still the almost perpendicular section left standing afforded ample field for inquiry and speculation. The bottom, or floor, consisted of rolled stones, or sea beach, in some places mixed or covered with stalagmitic concretion several inches thick. The lowest stratum, 3 feet thick, was composed of dark loam, with a mixture of decayed shells, principally of the *Mytilus edulis.*

Above this, extending round the cave, was a remarkable layer of shells of the *Patella vulgata*, varying from 1 to 3 feet deep, all in the finest possible state of preservation, and of a large size, many of them measuring upwards of 2 inches across. This extraordinary deposit of shells contained no admixture of sand or earthy matter, but lay pure and clean, as if heaped together by human agency. A few examples of *Turbo littoreus* of Linn. were picked up. About 8 feet from the floor we found a stratum of decayed animal matter, about a foot deep, with a layer of bones extending throughout the whole width of the cave. The teeth and bones were discovered in this layer, and, so far as yet observed, they belong chiefly to the Ruminantia, and are very similar to some of those from the Kirkdale cave, represented in the plates to Buckland's 'Reliquiæ Diluvianæ,' especially the deer-horns and teeth figured in plate 9, 2nd edition. The whole of the bones have been shattered, except the joints and other solid parts; on these we perceived marks, as if they had been gnawed by some animal. The only examples of carnivora yet met with are the head of a wild cat, and the jaws of a fox or wolf, with teeth belonging to animals of a larger species. About a foot from the floor we turned up part of the left parietal bone of a human skull, extremely thin, but compact, firm, and smooth as a piece of ivory. No other part of the human subject had been found, so far as our investigation proceeded. Two small pieces of a pipkin were also picked up, bearing evident marks of antiquity. The floor of the cave dips inward at an angle of about 10 degrees to the horizon, which leads to the supposition that there is a connexion with some other cavern into which the sea has had access by this opening, or that another cave had existed between it and the sea, through which the shells might have been carried to their present position. It is not improbable that another cave may be found a little to the west of the present, where the rock is hidden by the debris from above and the soil that has fallen from the upper grounds. Speculation on this subject at present would be idle, but we cannot refrain from alluding to the marked similarity which exists between the remains found in this cave and those found in that of Kirkdale,—the natural inference from which leads us to suppose that this also was a hyæna cave, and that remains of this animal may be found on further search being made.

On Granite. By Dr. Bialloblotzky.

On Coal at Ambisheg, Isle of Bute. By Dr. Black, *F.G.S.*

On the Elephant Remains at Ilford. By A. Brady.

The tusk of an enormous mammoth was discovered about two years since lying on its side, about 14 feet below the present surface of the soil. It belonged to an animal of the species *Elephas primigenius*, and is identical with the Siberian mammoth, and, I believe, with the one found in Behring's Straits. The tusk was decayed at each end, the extremities being gone, but the part preserved was over 9 feet long, and of proportionate bulk. Some idea may be formed from this of the huge size of the animal of which it formerly formed a part. It was very much incurved, being so much bent back that the bone was not more than 4 feet 2 or 3 inches across in any part. Owing to the nature of the soil, the whole tusk was very friable, most of the gluten of the ivory being decayed, so that great care was required in moving it to prevent it falling to pieces. Nearly a year afterwards a large tibia was obtained, and two molar teeth, probably belonging to the same animal, as they were not a great way from the tusk. One of the latter was very large, weighing about 12 lbs., though, from long use, much worn. About the same time, several bones of a large rhinoceros were found. These, from their more compact nature, were less decayed; and the tibia and one side of the jaw were very perfect, several teeth being *in situ*. The other half of the jaw was smashed by the workman's pick; several teeth were saved. Like those of the mammoth, they were very much worn. The species was supposed to be *Rh. leptorhinus*. Associated with these remains were some of the bones of a large ox, the horns and skull of which were very perfect, with several teeth *in situ*. There were also turned up, within the last month or two, some bones of a large ruminant, believed to be of the Megaceros, or Irish elk. About thirty years since, the late Dr. Buckland discovered the bones of a mammoth in this locality; and about the same time the late Mr. Gibson obtained the beautiful collection of bones now in the Royal College of Surgeons. Associated with the remains of those giants of ancient days, are the shells of *Planorbis, Unio, Cyclas, Paludina*, &c.: and there are now living in the Roden, and other tributary brooks in the neighbourhood, the *lineal* descendants of these fossils, the ancestors of which enjoyed the same sunshine as the mammoth and rhinoceros, the aristocracy of those days. Thus we have amongst us, living on the same estate as their ancestors, the humble Paludina, Planorbis, &c., forming, as it were, the link between the past and the present order of things.

On a Horseshoe Nail found in the Red Sandstone of Kingoodie. By Sir D. Brewster, *K.H., LL.D., F.R.S.*

On the Geology of Lower Egypt. By G. Buist, *LL.D., F.R.S., F.G.S.*

On the Submerged Forests of Caithness. By John Cleghorn, *Wick.*

The submerged forests of Caithness are found in the bays of the county into which streams empty themselves. We have them in Lybster Harbour, in Wick Bay, in Sinclair's Bay, and at the mouth of the Thurso.

These submerged forests are characterized by the vegetation of the districts through which the streams flow. In that at Lybster there are large trees prostrate, and finely comminuted peaty matter. In those at Wick, in the Links in Sinclair's Bay, and at Thurso, I have found no large trees; only birch twigs and peaty matter. Large trees grow only in the very sheltered districts of the county—in the hollows. The stream at Lybster runs in a deep ravine.

The trees and peaty matter in the submerged forest at Lybster are found below high-water mark, and, like the specimen exhibited in the section, are stratified. In Reiss Links, Sinclair's Bay, the peaty matter is covered with blown sand which is finely turfed over; but the small streams there have exposed the peat and made cuttings through it. The peaty stratum is from one to three feet thick, and from eight to ten feet above high-water mark. Similar peaty matter is frequently taken up on the flukes of their anchors by vessels in the bay. I infer that in favourable localities the peaty matter is continuous from the Links to the anchor ground.

The specimens exhibited are characteristic of our submerged forests generally, and their striking feature is their stratification, or rather lamination, they being in this respect wholly different from the living mosses of the county.

There is another feature of the peaty deposit in the Links to which I beg to call attention. Near the Castle of Ackergill, at the east end of the peaty stratum, we find it to be the impalpable matter of peat, and when dried and broken the fracture is lustrous and conchoidal; but further west we find the stratum to be twigs and the rougher matter of peat-bogs, very regularly and finely laminated.

This peat-bed then must have been laid down in deep water; and I infer that it must have been deposited in the deep water of the bay, from the circumstance that it is arranged along shore in the order in which the sand and gravel are arranged along the shores of the bay. Mr. Coode mentions that a crew landing on the Chessel Bank in a dark night can tell their position on the bank by the size of the pebbles around them; but it is true, not of the Chessel Bank only, but of all bays, of all firths, and of all seas, that the debris is laid along shore in a determinate order, which order is due to the regularity of the winds, and consequently of the currents. In Sinclair's Bay there is a sandy district, a gravely district, and a district of boulders; and in each of these districts there is a sub-arrangement determined by the weight in the materials. In the sandy district we have a siliceous region, and a region of shell-sand. Thus we see that the peaty matter here did not grow where it is now found. How then comes it to be in the Links? The sea is receding. This is proved by our river banks standing at a higher angle at the estuaries than further inland; the denuding process there has not been so long at work; they want the softness of the further inland banks. The high-angled banks, too, are terraced with what are commonly called sheep-walks, but which to my mind are incipient landslips—steps in the process of denudation, that process through which the softness, the swelling character of the interior banks has been attained. Another evidence of the sea's leaving our shores—retiring—is the Limpet (Patellæ) markings on the rocks, from where limpets now live, to far above high-water mark.

The sea then is receding gradually, and the submerged forests are emerging; they are therefore analogous to the wood deposits known to exist at the mouths of the large rivers of Europe, Asia, and America.

A Letter to Sir Charles Lyell *on the occurrence of a Land Shell and Reptiles in the South Joggins Coal-field, Nova Scotia. By* J. W. Dawson, *LL.D., F.G.S.*

[See Journal of the Geological Society of London.]

On certain Volcanic Rocks in Italy which appear to have been subjected to Metamorphic Action. By Professor Daubeny, *M.D., F.R.S., F.G.S.*

Dr. Daubeny called the attention of the Section to two products of volcanic action met with in Italy, the pecularities of which, he thought, had not been fully explained. The first of these is the Piperino rock, met with so extensively about Albano, near Rome, which is distingushed from ordinary tuff not only by its greater compactness and porphyritic aspect, but likewise by the occurrence in it of numerous laminæ of mica and crystals of augite, which tend to give it the appearance of a metamorphic rock, or of one which, although originally ejected as tuff, had been subsequently modified by the long-continued action of heat and pressure. The principal difficulty in the way of thus considering it arises from its alternation in several places with ordinary tuff, or with strata of loose scoriæ, as is well seen near Marino; so that it is difficult to conceive how the materials composing the Piperino could have been exposed to heat after their deposition in the form of tuff, without the intervening layers having been subjected to the same operation. The other volcanic product alluded to was the rock called Piperno, found near Naples, a brecciated material, in which wavy and nearly parallel streaks of a dark grey, brown, and often almost black colour, occur impacted in a matrix which is for the most part ash-grey, and seems, mineralogically speaking, to resemble trachyte. The imbedded masses occur generally elongated in the same direction, as are also the pores which occur in the midst of the mass. These circumstances have been accounted for by supposing a stream of molten trachyte to have invaded a congeries of fragments of ordinary lava, and to have brought about their partial fusion; but the Piperno seems to constitute a part of the great tufaceous deposit which overspreads the neighbourhood of Naples, to which no such metamorphic action is ascribable, and that which has been lately met with in the new road now constructing above the suburb of the Chiaja at Naples lies imbedded in the midst of ordinary tuff. Dr. Daubeny therefore conceives that the peculiarities presented by both the rocks alluded to require further elucidation, and that their study might tend to throw some new light upon the effects of metamorphic action upon rocks in general.

On the Constitution of the Earth. By the Rev. J. Dingle.

This paper was intended to be supplementary to one brought before the Association last year on "The Configuration of the Surface of the Earth." Its object was to obviate some objections to the theory then brought forward, arising from the supposed constitution of the earth's mass.

Among other objections to the fluidity of the earth's interior which the author endeavoured to controvert, he particularly referred to those which Mr. Hopkins is supposed to have substantiated by mathematical reasoning in his "Researches in Physical Geology," published in the 'Philosophical Transactions' between 1839 and 1842. He observed that these investigations are assumed to have proved more than the arguments warrant. The fluidity of the interior may be and probably is so imperfect, that what Mr. Hopkins calls the *effective crust*, may be sufficiently thick to accord with his deductions, while the actual crust may be comparatively thin.

The author regarded mathematical reasoning as inadequate to the solution of the question, and pointed out the necessity of relying on more obvious indications. He also showed that the hypothesis of a cavernous structure for the earth's interior is insufficient to account for the great volcanic lines and mountain systems, and concluded his paper in the following words:—

"The argument for the true physical character of the earth admits of a much wider induction of particulars than has generally been imagined. The general facts of geology indicate clearly that all the great masses of land in existence have, from the earliest period of the formation of a crust, been gradually rising with an irregular motion from beneath the level of the sea. Scientific men have been able to observe *directly*, one instance of this motion in Scandinavia; but every part of the land gives almost equally unequivocal indications of the same truth. Thus South America has evidently been tilted up into a slope, the whole continent having been heaved by a continuous force acting through innumerable ages. The volcanoes at its upper edge are but the mere outbreaks of its irregular action. And so in every part of the world, where the strata have not been much disturbed and broken by volcanic agency or denudation, we see the history of the land's emergence in the tracings of every successive deposit as it rose above the influence of the ocean. The southern part of our own island is little more than a series of these tracings. We see them in similar order redoubling part of the outline of North America, and we may find similar indications in every part of the world. All these things point to an interior fluid working slowly and solidifying gradually beneath. Let any one observe how any mass of molten matter, heaving from below and gradually hardening above, forms to itself a surface broken into angular and uneven pieces at different levels; and then, after taking into account the determination of the ocean currents, and allowing for the effect of other obvious agencies, he will be at no loss to account for the irregularities of the earth's crust, or remain in any doubt as to its real constitution, and the true course of its geological history. Its progress only affords a fresh instance how God can bring about the most varied and beautiful effects and the most beneficial results by the most simple means."

On the Coal Strata of North Staffordshire, with reference, particularly, to their Organic Remains. By R. GARNER, *F.L.S., and* W. MOLYNEUX.

It is pretty well known that the coal-fields in question repose upon strata of millstone grit, and these latter upon the mountain limestone, with its upper beds of shale. From the area of mountain limestone, situated at the east part of North Staffordshire, and constituting the southern extremity of what has been called the back-bone of England, the strata have a general dip westwards; but this dip is interrupted and the strata elevated along several anticlinal lines, running more or less north and south, and marked by bold ridges or *edges* of grit; so that several coal-troughs are formed. A cross section would therefore show the strata to be disposed in a zigzag way. On the surface of the largest coal-field, about 50 square miles, the great Potteries have risen, and from its strata 16,000 tons of coal are drawn weekly for manufacturing purposes alone, besides household fuel for 100,000 people, as well as coal and ironstone to feed about thirty smelting furnaces. A line of clay-pits, the purple clay of which is very different in quality from the fire-clays of the coal-measures, and which is accompanied by an extremely hard-cemented conglomerate, of a green or yellow colour, marks the south boundary of this principal field. These beds may perhaps be considered to belong to the coal strata, as in the Ordnance sheets; in some respects they seem as referable to the Permian. At the base of the most westerly ridge the limestone is again attainable, but differing in colour, &c. from that mentioned above on the east side of North Staffordshire; its fossils are frequently very small specimens of univalves and Bellerophon. This westerly ridge, constituting the west limit of the Pottery coal-field, diverges S.W., and the comparatively modern strata of new red sandstone are tilted up by it. It is not the original limit of the coal strata, for these are not only raised conformably to it, but identical beds of coal reoccur on the westerly or

Cheshire side. In other cases the coal appears to thin out as it approaches the grit hills. Denudation as well as elevation seems to have taken place, and the latter in some cases after the deposit of the red sandstone. In this Pottery coal-field the numerous faults run, more or less, at right angles with the lines of elevation, and from southerly falls it has fortunately happened that the seams are more widely attainable than they would have been without their occurrence. Some of the (geologically speaking) highest beds of coal are worked about 700 feet below the sea-level; others, upon Axedge, exist 1000 feet above it, and these appear to have been the first deposits. In this last narrow trough the coal strata seem bare and dissected to the naked eye, being imperfectly covered with herbage and reposing upon equally bare and jutting rocks of grit. The fossil *Aviculo-pecten* only appears to occur in the lowest strata to the east, whilst the *Microconchus carbonarius* is common in the upper. The coal-yielding beds may be said to consist of an upper and lower series in the principal coal-field; no known band of clay ironstone exists in the latter; though, in the present mineral-seeking times, an important bed of earthy hæmatite has been found very low in the series. The ichthyolites, to be mentioned, occur principally in the upper measures, as they are commonly found in ironstone or its shales. Some layers seem to consist almost entirely of these fish-remains with coprolites, but the former extremely fragmentary. The ironstone, No. 4 from the surface, called the *bassy mine*, is a remarkable bed, and may be identified through the whole area of the upper measures, being raised in enormous blocks, marked on their surface by great impressions of Stigmaria, and by flattened Uniones.

One or two dykes of greenstone occur in the bunter sandstone to the south of the Pottery coal-field, and metamorphosed grits at Mow Cop (Sax. or as well Brit.) in the westerly ridge, and at Fenton Park; the second greenish in colour and enclosing round nodules of hæmatite. The drifts or gravels of North Staffordshire appear to be of, at least, four or five kinds: the northern drift with fragments of *Venerupis* and other shells; a second gravel with fragments of whitish chalk-flints and sometimes Ananchytes; both these gravels occurring in the southern lower lands, but the first rather to the east and the second to the west; next the gravels of the bunter sandstone, often forming hills of a good elevation and composed mostly of characteristic red quartz pebbles, marked by cloudy white spots, greenstone, curious decaying agates, mountain limestone, and lower Silurian pieces, as well as white quartz and black jasper, also grit and coal. On the area of the coal-fields a coarse gravel of less rounded pieces occurs, mountain limestone, grit, and greenstone being the constituents; also, in the surface clays, blocks or boulders of greenstone or porphyry, red and white granite, and grit, more or less rounded, and sometimes weighing several tons. From the sides of some of these valleys, of the bunter sandstone formation, the rocks often jut out in a horizontal direction, giving the idea that such valleys must have been formed by the action of water. The millstone grit often presents smooth or polished surfaces (slickensides?), but this even in the quarry.

Coal-plants, as Calamites, are frequent in the Permian. In the coal strata the authors lately measured the but or trunk of a Sigillaria more than a yard across, its roots being given off exactly in the cruciform way, and bifurcating at equal distances of about a foot. When broken, these root-trunks presented an impression very like the leaf of a *Blechnum*, but which they suppose is due to the compressed processes given off from a central fibrous rod. They also appear to be compound. It is also curious how many of the trunks of these trees contain other vegetable remains in the clayey sandstone of their interior, such as large Calamites. Certain heart-shaped bodies abound in the ironstone, with the mark of the insertion of a hollow stem above: these the authors think may be the roots of Calamites or similar plants, the cylindrical stems which seem to belong to them ending rather obtusely, smooth, unjointed, and often containing pyrites of zinc. Then again are found convex, hemispherical bodies, with a tubercular surface, and cellular within; smaller ones occurring gregariously. Circular or reniform markings occur in the shale of the bassy mine, above alluded to, presenting somewhat the appearance of a peltate or cordate aquatic leaf; but they go through several laminæ of shale. There are also large grass-like leaves (Poacites?), a large and a small Ulodendron, two Haloniæ, fine Asterophyllites and Sphenophylla, with other commoner fossils.

The large-leaved *Neuropteris cordata*, a Sphenopteris with a fucus-like leaf of large size, and another quite filiform, have also been found by the authors. The following are the more interesting ichthyic remains, as far as they can identify them by Agassiz:—

Dipterus. Part of the head, and plates.

Palæoniscus. Scales, and a portion of the fish (*ornatissimus, Duvernoyii*).

Gyrolepis. The hinder half of the fish.

Cœlacanthus. Scales and fins.

Platysomus. Fragments of the fish, and numerous scales.

Rhizodus. Most of the fish, and the sharp- and curve-pointed striated teeth.

Holoptychius. Very large plates and parts of the fish, the upper jaw with double rows of large and small striated teeth.

Ctenodus. Two or three pieces.

Megalichthys. The plates are very common as well as the teeth, a cranial plate 6 inches wide, vertebræ 2 inches; also the jaw with teeth, and the tail found by Mr. Ward.

Saurichthys. Teeth swollen at the bottom, striated, and more curved than the commoner teeth of the last genus.

Ctenacanthus. The armature is not rare, a fine and perfect one found by Mr. Ward.

Hybodus. The teeth with crumpled base, one large middle cusp, and two or three side ones on each side.

Diplodus. The supposed teeth are very common, with three or more fangs. A tooth straight, compressed, lanceolato-conical, $1\frac{1}{4}$ inch in length: if it belongs to *Diplodus,* the size must be unusual.

Ctenoptychius. The beautiful teeth are not very rare; there appears to be numerous species (*apicalis, pectinatus,* and *denticulatus*). A tooth of, apparently, a new genus, very small, with truncate base and eight or more clustering slender-pointed cusps at irregular altitudes.

Petalodus. Remains of several species.

Helodus simplex. Base of teeth excavated, the summit simple and blunt.

Pleuracanthus. These curious armatures are rare, but we have found one very perfect in cannel; some imperfect specimens have the central part compressed, and the processes less marked.

Onchus (?). These sword-shaped rays or spines, moulded on the concave edge, are extremely common.

Orthacanthus. These formidable weapons are frequent, and very long, a foot or more; they are difficult to get out unbroken. A smaller and more conical armature without term.

Leptacanthus.

Gyracanthus. Common, and of two or more species.

Besides the above, numerous fragments have been collected, of more or less interest, some considered to be novelties by Sir P. Egerton: also nine or ten species of the bivalve *Anthracosia.* The authors are rather reluctant to give names, but the following epithets may almost suffice to distinguish them:—*A. triangularis, dactylus, unio, anodon, retrocompressa, alata, nucula, oblonga. costata.*

The hillocks raised by annelides, ripple-marks, and very large impressions of bivalves of two or three forms occur in the flagstone of the millstone grit; also transverse sections of plants, either round or obliquely indicated, as if blown down.

From the mountain limestone, occupying about 40 square miles, more than 200 species of Mollusca have been collected, but this principally by a friend, Mr. Carrington, a village schoolmaster. Amongst the more interesting species are Conularia, species of Pteronites, Pleurorhynchus; rare Pleurotomariæ, Goniatites, and Nautili; the *Orth. paradoxus,* or one similar to that from Ireland figured by Sowerby; abundance of corals; many pelvic plates of Crinoida, and about ten species of Trilobites, all small, and rarely entire. The latter most abound with the fry of Terebratulæ. Mr. Carrington has also found traces of fish. The limestone shale has some obscure impressions of bivalves. With respect to vegetable remains, little has been discovered: certain supposed stems or twigs, of an enamelled appearance, are siliceous when chemically examined; and the received opinion seems to be that other curious algæform markings of the limestone are mere infiltrations.

On the Chronology of the Trap Rocks of Scotland. By A. Geikie, *F.G.S.*

The points to be proved were—first, that there is sufficient abundance of felspathic matter in the grits of the Silurian region of the Lammermoors to warrant the inference that felspathic matter was either ejected during the formation of these grits, or already existed in considerable abundance on the surface. Second, that the Silurians of the Lammermoors are traversed by numerous dykes of felstone, some of which may have been ejected during a contortion of the Lower Silurian previous to the deposition of the Upper. Third, that the Old Red Sandstone period was marked by powerful and long-continued volcanic activity, in several centres, as the Sidlaws, the Ochils, the Pentlands, and part of the hills of Lanark. Fourth, that the Carboniferous period was characterized by the especial abundance and activity of its volcanic centres—so much so that there is not a well-defined zone of carboniferous beds which does not, at some part of the Lothians, display its intercalated sheets of ash or greenstone; but that these eruptions were markedly local alike in their extent and in the character of the erupted material. Fifth, that after the carboniferous series, there is a great gap in the chronology of the Scottish trap-rocks, the next traces of subterranean movement being discernible in the lias of Skye; but that contemporaneous igneous rocks are not found until towards the top of the middle oolite, where among estuarine limestones and shales, there occur in Skye and adjacent islands enormous sheets of greenstone and basalt. Sixth, that, as upper secondary rocks have still to be determined in the Hebrides, we have, at present, to pass from the oolitic traps of Skye to the basalts and ashes of Mull, which, as shown by their associated fossils, are tertiary, and probably miocene. Lastly, that the later basalts and ashes of Arthur's Seat ought probably to be referred to the later secondary, or older tertiary period.

On Canadian Caverns. By George D. Gibb, *M.D., M.A., F.G.S., Member of the Canadian Institute.*

The prominent feature of a large portion of the Province of Canada is the presence of various limestone rocks belonging to the Silurian formations. Until lately, the existence of caverns in these rocks, as well as in those lying subjacent, namely, the Laurentian of Sir William Logan, was almost unknown; but owing to the labours of the Canadian Geological Survey, and of several private individuals, a number have been discovered, at distances remote from one another, which it is the object of the present memoir to notice.

For convenience of description, these caverns are divided into two classes; the *first* comprises those which are at the present time washed by the waters of lakes, seas, and rivers, including arched, perforated, flowerpot, and pillared rocks, which have at one time formed the boundaries or walls of caverns, and all of them unquestionably the result of aqueous action. The *second* comprises caverns and subterranean passages, which are situated on dry land, and, so far as we know, not attributable to the same cause in their origin as in the first, or at least not applied in the same manner.

In the *first class* are included—

1. Caverns in the shores of the Magdalen Islands.
2. Caverns and arched rocks at Percé, Gaspe.
3. Gothic arched recesses, Gaspe Bay.
4. The "Old Woman," or Flowerpot Rock, at Cape Gaspe.
5. Little river caverns, Bay of Chaleur.
6. Arched and flowerpot rocks of the Mingan Islands.
7. Pillar sandstones, north coast of Gaspe.
8. Niagara Caverns.
9. Flowerpot Island, Lake Huron.
10. Perforations and caverns of Michilimacinac, Lake Huron.
11. The Pictured Rocks, Lake Superior.
12. St. Ignatius Caverns, Lake Superior.

13. Pilasters of Mammelles, Lake Superior.
14. Thunder Mountain and Paté Island pilasters, Lake Superior.

In the *second class* are—

15. The Steinhauer Cavern, Labrador.
16. The basaltic caverns of Henley Island.
17. Empty basaltic dykes of Mecattina.
18. Bigsby's Cavern, Murray Bay.
19. Bouchette's Cavern, Kildare.
20. Gibb's Cavern, Montreal.
21. Probable caverns at Chatham, on the Ottawa.
22. Colquhoun's Cavern, Lanark.
23. Quartz Cavern, Leeds.
24. Probable caverns at Kingston, Lake Ontario.
25. Mono Cavern.
26. Eramosa Cavern.
27. Cavern in the Bass Islands, Lake Erie.
28. Subterranean passages in the Great Manitoulin Island, Lake Huron.
29. Murray's Cavern and Subterranean River, Ottawa.
30. Probable caverns in Iron Island, Lake Nipissing.

All these are particularly described in the author's memoir. The majority of those in the first class are on a level with the water, whilst the remainder are elevated above, varying from a few to upwards of 60 feet. In the second class the level varies, but nearly all are above that of the sea, and none penetrate the earth to a considerable depth; but this may be found to be otherwise as the explorations are continued. In none have animal remains been found excepting in one instance, and they were discovered loose and not imbedded in stalagmite; and, so far as I am aware, not a single object, such as a flint arrow-head or spear, used by the ancient inhabitants of the country, has been observed: this part of the inquiry has still to be worked out, as many of the caverns have been but very partially explored. Interesting discoveries are yet hoped for in the district of country in which exist the huge caverns of Mono and Eramosa, in the Niagara limestone rocks of the Upper Silurian formation. A correct account of the geological formation in which the caverns are found is given; and, taking the two classes of caverns together as representing thirty distinct series of cavernous objects, 1 is found in the New Red Sandstone; 2 in the Devonian or Old Red; 7 in the limestones of the Upper, 4 in those of the Middle, and 6 in those of the Lower Silurian formation; 3 in the Huronian rocks of Sir William Logan, and 7 in the Laurentian rocks of the same geologist. In the last of these they are present in the interstratified bands of crystalline limestone, characteristic of this formation in Canada.

With a few exceptions, nearly all occur in limestone rocks, and their origin has depended upon various causes. The first fourteen, which compose the first division, are the results of aqueous action, as their situation, present condition, and general description clearly prove. Perhaps an exception might be taken to the formation of pilasters and Gothic arched recesses, which are more properly attributable to atmospheric influences. Volcanic agency has given origin to the basaltic dykes of Mecattina, the basalt of Henley Island, Bouchette's and Gibb's caverns. The same cause has most likely influenced the subterranean passages of Manitoulin and Murray's cavern.

On the other hand, Bigsby's cavern, Colquhoun's, the Mono and Eramosa, and Bass Islands caverns, were formed by some other agency, in which a slow disintegration of the rocks has occurred from chemical or other causes, and the soluble particles have been removed by the influence of water, entering by percolation from above, or between the neighbouring layers of rock. The origin of the quartz cavern was by the explosion of a pyritous vein.

The bones found in Colquhoun's cavern were supposed to be those of a species of deer, and occurred chiefly in a heap, although many others were scattered among the debris on the floor. They were transmitted to Dr. Buckland for examination and description some thirty years ago, but no account of them ever appeared.

On some Basaltic Formations in Northumberland. *By* WILLIAM SYDNEY GIBSON, *M.A., F.S.A., F.G.S.*

The basaltic formations in Northumberland not only contribute to the picturesque outline and the wildness of much of its scenery, but present some remarkable features in their structure and in the manner of their association with other rocks.

A range of basalt traverses the county from south-west to north-east, in a ridge or belt of varying and often considerable height, but inconsiderable breadth, entering Northumberland near the Cumbrian border. This ridge first begins in the dale or "forest" of the Lune, and sweeps round the great western escarpment of the limestone ranges of Cross-Fell and Tynedale-Fell; then, curving towards Thirlwall on the border of Cumberland, it runs from thence north-eastward with bold escarpments towards the north, and crossing the North Tyne, extends to the sea-coast at Howick; it then rises at Bamburgh, and after a tortuous course to the north-west, ends in the low range of hills called the Kyloe Crags. The rocky group or "seventeen sister-satellites" of Farne are a seaward prolongation of the great basaltic range. Basaltic veins or dykes also run towards the coast of the county (as at Holy Island, Beadnell, andTynemouth), and seem to have a direction transverse to the great ridge.

In the western part of the county, the basaltic crags are associated with that wonderful monument of Roman occupation—the Great Wall, its builders having availed themselves of the precipitous ridges, and carried the wall above many a bold escarpment of basaltic rock. A crest of this formation near Wall-town, which was formerly crowned by a Roman Mile-Castle of the Wall, is 800 feet above the sea-level; and at a Roman camp to the westward, known as Sewingsheles, the summit attains the height of 960 feet. In this wild district, once adjacent to populous Roman Stations, but where now only the moor-fowl dwells among the heather of neighbouring wastes, are the lonely sheets of water known as the Northumberland Lakes, one of which, called Crag Lough, lies at the foot of the basaltic cliffs.

In the northern part of the county the basalt likewise forms rocky masses of considerable height, often precipitous on their western side, and culminating at one place at 570 feet above the level of the sea. Many of these eminences have been chosen for the site of Castles, as at Bamburgh, Holy Island and Dunstanburgh, where the caverned rocks of columnar basalt rise 100 feet above the surging waves. At Bamburgh (an important citadel from days of Saxon royalty) the draw-well of the fortress has been sunk through 75 feet of basaltic rock, and through a like thickness of the fine-grained reddish tinted sandstone on which it rests. On the rocky islets of Farne the basalt even exceeds this thickness.

The isolated, metamorphic and dislocated condition of the beds of sandstone, limestone, and shale on some of the Farne islands, seems to indicate that the basalt flowed in its igneous state over these lower groups of the limestone series. On the coast at Howick, a little to the south, the basalt appears in the form of dykes which intersect the cliffs of carboniferous limestone, shale and sandstone. A formation of basalt, which seems to have overflowed after the deposit of this group, overlies it. Elsewhere in Northumberland a stratiform basalt is found associated with the carboniferous rocks, and in some localities is interstratified with them; thus, a bold columnar cliff called Ratcheugh Crag, near Alnwick, one of the range of basaltic eminences which run inland from the coast at Dunstanburgh, is capped with the carboniferous limestone. Another basaltic eminence between Alnwick and the coast rests on beds of blue limestone and metamorphic shales, which in some localities Mr. George Tate of Alnwick, F.G.S., a diligent and able naturalist, found to have been converted into a porcelain jasper, and where in direct contact with the basalt, into a black mineral of conchoidal fracture. At Ratcheugh some of the limestones above the basalt have been changed into granular marble.

In some localities of this carboniferous limestone district, as at Howick and Bamburgh and on the Farne, the rocks have been disturbed by an eruption of basalt; and it occurs both as an injected dyke and an overflowing lava, and seems to indicate successive volcanic outbursts during as well as subsequent to the era of those formations.

The author adverted to another formation conspicuous in the northern and eastern regions of Northumberland—namely the Boulder-clay. This formation is largely developed on the eastern side of that range of sandstone hills which extends in a south-westerly direction from Kyloe to Alnwick Moor. In some places the boulder clay constitutes long hills with steep ascents, and isolated mounds which rise sometimes to a height of 25 feet and resemble ancient tumuli. There are, moreover, hills and ridges of diluvial gravel, clay, and pebbles, which bear a strong resemblance to lateral moraines, and may be attributable to the glaciers of a former age. A tortuous ridge of hills at North Charlton, between Alnwick and Belford, certainly resembles a lateral moraine; and similar mounds are traced over a considerable portion of the district into which the eastern valleys of the Cheviots descend. The boulders and fragments of Scottish mountains which are found in this boulder-clay formation, and which strew the beds of rivers in Northumberland, and indeed the face of the country, cannot, however, be conceived to have been transported by any other agency than that of ice. It seems not at all improbable that the ponderous and far-travelled blocks were borne by icebergs to the places where they rest, at a time when the climate of Northumberland was of an arctic character, and when its elevated regions alone stood above the sea. It seems worthy of remark, that beneath an overlying boulder-clay in the Hawkhill quarry above referred to, the limestone bed *in situ* is scratched and grooved, and in some places polished, the markings having a general direction from north to south.

The author referred in conclusion to the contributions made by Mr. Tate to our knowledge of the Basalt and the Basaltic dykes of Northumberland, and to the questions raised by those formations.

On Sections along the Southern Flanks of the Grampians. *By* Professor Harkness, *F.R.S., F.G.S.*

The rocky masses which have been exposed, by the action of the German Ocean, in the neighbourhood of Stonehaven, afford a considerable insight into the structure of the southern flanks of the Grampians. Here we have, in the neighbourhood of Dunotter Castle, the conglomeratic portion of the middle member of the Old Red Sandstone formation well exhibited, and possessing a S.S.E. dip at an angle of about 80°. Beneath this conglomerate, immediately south of Stonehaven, the Forfarshire flags occur, having the same inclination, and marked by the grey colour which they usually manifest when worked for commercial purposes. These Forfarshire flags occupy the coast northward to Garron Point; but as they leave the old red conglomerates, they lose their ordinary grey colour; and near their base, as here exposed, they assume a purple aspect.

At Garron Point they come abruptly in contact with the metamorphic rocks which constitute the great mass of the Grampian range. There is, however, a total discordance in the arrangement of these two series of rocks; for while the Old Red Sandstone formation dips S.S.E. at a high angle, the metamorphic rocks are inclined N.N.W. at about 70°. This mode of relative arrangement Professor Harkness has found to prevail in all the sections of the interior over two-thirds of the flanks of the Grampians. In many instances, however, thick masses of trap intervene, separating the Old Red Sandstone on the S.E. from the metamorphic rocks on the N.W. As regards the association of the metamorphic rocks in this area, the lower portions consist of clay-slate, to which succeeds mica-schist overlaid by gneiss, an arrangement similar to that shown in the section attached to Professor Nicol's map, and leading to the inference that in this portion of the Grampians the clay-slate is the oldest rock of the metamorphic series.

On the Yellow Sandstones of Elgin and Lossiemouth. *By* Professor Harkness, *F.R.S., F.G.S.*

The strata which lie north of the town of Elgin, and which have been described by Sir Roderick Murchison in the Quarterly Journal of the Geol. Soc. vol. xv., consist for the most part of yellow sandstones capped with limestone. These, at

Lossiemouth, at Spynie quarry, and at Findrassie quarry, have afforded reptilian remains of such a nature as to show considerable affinity to the palæontology of the Trias. Notwithstanding this circumstance, there is strong reason to infer that the strata in the district are the representatives of the upper portion of the Old Red Sandstone series. From an examination of the several localities where the rocks are exposed north of Elgin, Professor Harkness has been induced to adopt the conclusions of Sir Roderick Murchison, and other geologists who have inspected this neighbourhood, and has arrived at the inference that the strata here appertain to the Old Red Sandstone formation. From the ridge in which the Bishops' Mill quarries occur, immediately north of the river Lossie, and where Holoptychian fishes are found, to Spynie hill, there is a constant N.N.W. dip at about 10°, and the lithology of the deposits, as exposed in this interval, shows an intimate relation among the arenaceous rocks which occupy this area. The rocks are to a considerable extent masked by debris; but whenever these are apparent, they manifest no traces of faults of such an extent as would disconnect the Holoptychian yielding strata from the reptilian beds which occur in this portion of Moray.

On the Origin of the Ossiferous Caverns at Oreston. *By* Henry C. Hodge.

The author referred, in the first place, to the description of this cavern given by Mr. Whidby, and continued:—

"The statements so confidently made by Mr. Whidby as to the perfect enclosure of the caverns by solid limestone, have been confirmed by my own observations, and this fact has not failed to surprise even the workmen engaged in the quarry; but it must be evident that at some period an opening did exist, and it occurred to me that such might be most successfully sought for between the surfaces of the beds of which the masses of limestone are composed. No satisfactory conclusion could be drawn from careful examination of the rock during the opening of the cavern; but on looking narrowly into the beds of limestone in the progress of the workings, it was found that a thin seam of purple calcareous clay-slate was interposed between the neighbouring beds of limestone, at *about* the same parallel as that in which the caverns were met with. On further investigation, it was discovered that alternations of this purple slate with the limestone were not unfrequent, but the laminæ of slate were in most cases so intimately blended with the limestone beds, as to form really a solid mass of compact rock; and on looking into the structure of the more evident layers of the slate, it was ascertained that in some parts they were much more calcareous than in others, and that small portions of limestone, having similar physical characters to those of the surrounding rock, were interspersed at varying intervals. In other places, the slaty layers were in a state of decomposition, red and reddish white clay being formed as its result; and on tracing a layer of this kind through the side of a cavern laid open during the workings, it was seen that portions of it were so disintegrated as to be easily pulled from their position, the seam being, in its most solid portions, composed merely of layers of limestone fragments with interposed clay and red sand,—the whole, apparently, kept in place by the accidental infiltration of calcareous matter. Here, then, were facts that might enable me to account for the clay found in the caverns, and afford a means through which the beds of limestone may have been caused to separate from each other. Again, it was discovered that some of the hollows in the adjoining limestone were stained with a black earthy substance, found, on analysis, to be composed of the peroxides of iron and manganese, these having evidently proceeded from the decomposition of a variety of dolomite very generally present in this limestone,—not exhibiting, however, any definite mode of deposit in it, but passing through its beds in the most irregular manner. From these phenomena, it appeared reasonable to conclude that the decomposition of the slate in the layers, through the combined agency of water and carbonic acid, had opened a communication with the external air to the above-named irregular masses of dolomite (the unchanged limestone fragments of the slate serving to keep the beds from close contact with each other), and that, in this way, the carbonates of iron and manganese contained in them had been converted into peroxides, and the evolved carbonic acid proceeding from their decomposition, combining with the remaining constituents of the dolomite, had formed bicarbonates, readily removeable by the agency of percolating water. In this way, it is possible not merely to account for the formation of the caverns, and a means of access to them, but at the same time to discover what are the causes still in operation which give rise to the production of stalactite, and occasion the irregular dolomization of the limestone,—it being evident that the percolating waters charged with bicarbonates of lime, magnesia, &c., may, by a loss of carbonic acid, deposit insoluble carbonate of lime in the form of stalactite, and becoming by this means richer in bicarbonate of magnesia, act chemically on the neighbouring limestone, converting it into dolomite.

"To test the correctness of these views, a very careful examination of the clay below the bones was instituted; it was extremely tenacious, and of a dark reddish brown colour; patches of red clay were visible in some places; and in other parts of the mass distinct yellow and black layers were apparent, and nodules, or, more strictly speaking, irregular masses of impure ochrey red iron ore, together with black rounded fragments, evidently arising from the decomposition of a dolomite similar to that before alluded to; for in the larger fragments this rock was distinctly visible on fracture; and in one or two instances, in which the masses were larger than usual, a brown zone was observable between the black external coating, and the central nearly unaltered dolomite; large and small masses of the common limestone rock of the quarry were also found in the clay, their surface being honeycombed as if by exposure to the long-continued action of carbonated waters. These phenomena may justly be explained on the supposition that the irregular masses of ochrey iron ore had been derived from the decomposed slaty seams, confirmatory appearances being not unfrequent in other limestone beds connected with the same series of rocks, the slate in these alternating with the limestone on a large scale, and containing irregular nodules of impure iron ore—a red oxide of iron being frequently visible at the points of junction. The varied colour of the clay may also be accounted for by the gradual admixture with it of the red oxide of iron from the slaty seams, and the black oxide of manganese accompanied by yellow hydrated peroxide of iron from the dolomitic rock, which may be concluded to have formed a part only of the walls of the cavern,—the honeycombed limestone fragments resulting from the displacement of other portions of previously-fissured limestone rock through the agency of aqueous carbonic acid. The most careful examination presented no facts that at all appeared of an opposing character; the clay was diligently searched, and some of its laminated portions, having a sandy appearance, were examined by the microscope for the siliceous coverings of infusoria, minute rounded grains of sand, and any other matter that might suggest the washing in of the contents of the cavern through free communication of its opening with external waters; nothing was, however, discovered but very minute fragments of slate, still further confirmatory of the position before advanced."

The author assigns reasons for adopting the opinion that the bones were introduced to Oreston Cave by animal agency, and not by accidental falling into fissures.

He enumerates the principal remains found in the cavern, viz. of the thick-skinned quadrupeds at least four genera,—Elephant, Rhinoceros, Horse, Ass or Zebra, and Hog. Of Carnivora, Bears of two species, *Felis*, Wolf, and a small rodent.

The ruminants probably included one or two species of elk or deer, and two or three animals allied to the ox. Teeth of the sheep or goat were also brought from the clay, but there is reason to be doubtful about the genuineness of many of the last-named specimens.

Among the remains of animals of the deer-tribe, is especially mentioned an interesting fragment of jaw, containing several teeth, developed by me with some pains from a large and nearly solid mass of stalagmitic matter, containing various other imbedded bones. There occurred too a very few fractured specimens of teeth suggestive of those of a giraffe (this possibility having been ascertained by comparison with figures of fossil teeth contained in a paper by Dr. Falconer and Capt. Cautley, in the 'Proceedings of the Geological Society of London'), and a small horn core may, it is presumed, also indicate the presence of an animal allied to a species of this interesting quadruped *.

* Two premolars of a Camel.

"In beds of limestone existing further to the east of those in which the just now mentioned fossil bones occurred, and which are evidently a continuation of the same series of rocks, little or no dolomite is included; they are also particularly free from caverns and generally from stalactitic deposits, presenting us with similar limestone rocks, for the most part unaltered by those changes which produce the phenomena of dolomization and caverns. These rocks are coloured black by the oxides of iron and manganese, and are traversed by numerous white calcareous veins; they form a part of the black marble so frequently employed for statuary purposes in this part of England. Distinct bluish-black slate and argillaceous hydraulic limestone beds are of very frequent occurrence in them, the beds containing occasionally iron pyrites, which, by the action of the weather, tinge the surfaces of the argillaceous and calcareous rocks of a rusty yellow colour. Applying now the above facts to account for the alteration of our cavern-containing rocks, we may legitimately suppose that their previously contained pyrites might by its decomposition yield a supply of sulphuric acid and sulphate of iron, and that these compounds, reacting upon the limestone in their neighbourhood, would (in presence of the air) finally produce sulphate of lime and peroxide of iron—the disengaged carbonic acid at the same time generated, affording the required means for effecting (in presence of moisture) the decomposition of its slaty layers; these in their thus disintegrated condition being afterwards compressed by means of superposed beds of limestone into a compact series of beds identical with those of our quarry, and coloured purple in their slaty seams by the above-mentioned peroxides of iron and manganese,—the bicarbonates of magnesia (and also the bicarbonates of iron and manganese) required to produce dolomization being at the same time formed by the action of the carbonic acid upon the masses of limestone, which is found on analysis to contain a sufficiently notable proportion of the necessary ingredients.

"But the physical evidence that these limestone beds are truly rocks of the black marble series, altered by chemical changes in them, allied to those now pointed out, does not alone rest on the similarity of their strata, allowance being made for the effects of such changes; the hollow cavities of the black marble are occasionally lined with acute scalene dodecahedrons of calcareous spar, and in the supposed altered series of rocks similar crystals are met with, these being generally corroded on their surface, and thus affording an evidence of a change in the conditions existing after their formation. In connexion with the deposits of stalactite, and in numerous small cavities in the dolomite, other crystals of calc-spar are not unfrequent; but under both these circumstances they exhibit different forms, those of the stalactite being generally acute rhombohedrons, whilst the dolomitic cavities are lined with crystals having the figure of obtuse rhombohedrons, combined occasionally with the planes of a second rhombohedron, which is more acute. There are, moreover, in these altered strata, instances of the formation of a second crop of crystals in the cavities still occupied by the acutely scalenohedral forms; and in all the cases I have had an opportunity of observing, these secondary crystals invariably contain obtusely rhombohedral surfaces. I may also add that there may be considered to be good evidence that the causes connected with the original formation of dolomite took place under conditions very different from those existing at the present day; for not only does the iron pyrites belong to a very persistent variety of that mineral (no marcasite being mixed with it), but the oxide finally seen to result from its decomposition is not a yellow-brown hydrate, like that of the present day, but a red anhydrous peroxide, which would not have been likely unless the temperature at the time was somewhat elevated.

"During the progress of the study of these rocks, I was able to obtain physical evidence of the presence of all the chemical compounds before described as occurring in them, sulphate of lime alone excepted; this, it may be remembered, I supposed to have been removed by the agency of water; and that means adequate for the removal of this somewhat soluble salt existed, was amply proved by the very numerous caverns produced by the decomposition of the dolomite to which so frequent reference has been made. In the lower strata of the quarry the workmen arrived at two very large openings of this kind, in the immediate neighbourhood of the bone cavern, and that these communicated with a plentiful supply of water was easily proved by the splashing sound heard when stones were thrown into them.

"There remain a few other facts which doubtless have an important bearing on the former condition of the bone caverns:—

"The stratified beds of the Plymouth limestone dip most generally to the south at about the high angle of 45°; there are, however, exceptions to this general rule, in certain places the beds exhibiting more or less basin-shaped depressions, caused, we may legitimately presume, by the undermining of their foundation through the decomposition of the before-mentioned irregularly distributed dolomite. If this be true, and similar causes have during former geological periods been in constant operation, the entire strata of this limestone may in their mass have undergone considerable subsidence,—a presumption corroborated by the presence on its northern boundary of an older series of unfossiliferous purple and grey slates of immense thickness, having a conforming dip of 45°, but now seen to lie at a considerably higher elevation. A second inference may also be deduced, viz. that, owing to such causes, the bone caves, at the time they are supposed to have been inhabited by carnivora, might have been situated at a much greater elevation than that at which we now discover them to be, affording these animals a dry and comfortable retreat in the mountain for devouring their prey. The dislocation of these rocks caused by their subsidence would afford, moreover, the necessary mechanical force required to separate in the soft and decomposing slaty layers, the limestone beds from one another, affording in this way suitable openings to the animals for entrance to and egress from their caves; the further subsidence *again* giving rise to displacements of the strata and hermetically closing them, until by still further mechanical change, an entrance being given to calcareous waters, they deposited the stalactite and stalagmite now sometimes found within them. And it may also be deduced from such considerations, that even during the human period the opening of these bone caves may have been possible, and that savage races using their dry and capacious chambers as a place of residence, and leaving their easily procurable flint hammers on their exit, they may through similar chemical and mechanical changes have once more been closed by the infiltration of stalactitic deposits. With respect, however, to this subject, I will not dwell upon it further than to remark, that although we can never bring forward arguments having the conclusiveness of eye-witnesses' testimony against the contemporaneity of man with the extinct mammoth and his congeners, the facts I have stated, will, if properly considered, tend to demonstrate that not merely is there no geological evidence whatever to prove their co-existence, but that all the apparently powerful arguments based upon the occurrence of his remains in ossiferous caverns, may be merely deceptive and of no real significance or certainty whatever, as their presence in them may be easily accounted for through the operation of natural and still exciting causes.

"Again, there has been observed in the neighbourhood, and at a distance of not more than two miles from the above rocks, the remains of a raised beach on the coast 15 feet above the present level of the ocean, and traces of others have been met with in various parts of the adjoining district. These raised beaches may at first sight appear incompatible with the view of a general subsidence of the neighbouring strata, but it will on consideration be evident that the formation of a large valley through the falling in of very considerable stratified masses, would naturally produce an upraising at the sides of the depression. In the neighbourhood referred to (that of the Hoe), it may be seen that a great part of the town of Plymouth occupies such a valley, bounded on the south by the limestone hills of the Hoe, and on the north by the high strata of purple slate before referred to. Following out the above idea, and supposing that there has been in past geological time a general sinking of the land in the northern part of our hemisphere, it is not difficult to account for a colder climate, though much greater elevation and more general distribution of the land, prior to these changes,—and it may be easily explained why raised beaches containing shells of arctic type may be compatible with such general depression; and these and other chemical changes acting below the surface of the rocks, and accelerated by the mechanical opening of their fissures through the freezing of water in them, may be reasonably supposed to have in some instances produced sudden floods of water accompanied by fields of ice, accounting for the presence of remains of thick-skinned monsters in the ice and frozen soil of Siberia."

On the Connexion of the Granite with the Stratified Rocks in Aberdeenshire. *By* T. F. Jamieson.

In many geological writings the granite and other igneous rocks are represented as having heaved up the overlying strata—hereabouts, however, they seem more frequently to have heaved them down; or in other words the sedimentary rocks dip towards, and apparently into or underneath the granite. Thus, on the south border of the great outburst of red syenite at Peterhead, the gneiss or mica-slate is seen along the coast dipping towards it, and the same is apparently the case with some granitic masses to the west of Ellon. To appeal, however, to a grander instance, take the vast igneous expanse of the Ben Macdui group, and along its south border at Braemar the huge mountains of quartzy gneiss come up, almost in horizontal regular strata, with, however, a slight southerly dip, until they cross the valley of the Dee, when they fold over into the base of the great granitic mass of Ben-a-Buird. In the Isle of Skye, also, the lias strata along the coast of Kilmuir dip into the huge outburst of trap that forms all the centre of that part of the island. The igneous rock in this case has apparently burst through a great rent of the lias and overflowed it, the edges of the sedimentary strata sinking down into the fused mass. With regard to the granite, the case perhaps somewhat differs. This rock is of more recent origin than the gneiss, seeing that the latter is disturbed, altered, and penetrated by it. The intense subterranean heat in approaching the thick masses of these old beds from below must have gradually melted them; and their immense weight would press down the unmelted edges into the pasty mass beneath—just as in heating a pot of lead the solid crust sinks down into the liquid metal. The granite may be in some measure the gneiss fused and crystallized under the pressure of the overlying masses of the stratified beds.

On the Drift Beds and Boulders of the North of Scotland. *By* T. F. Jamieson.

Drift beds, deposited from water, and containing striated fragments of rock, had been traced by the writer from the sea coast to the central regions of the Highlands; thinning out on the Perthshire hills near Killiekrankie at the height of 1500 feet, and resting on a surface of rock polished and furrowed as if by the passage of ice. These ice-furrows were also found passing over the crest of a hill in the same neighbourhood upwards of 2000 feet high. In the Braemar district similar beds of drift were traced up all the higher glens to the slopes of the Ben Muickdhui mountains, and to elevations exceeding 2000 feet, still preserving the aspect of an aqueous deposit, but more gravelly in texture and containing fewer, and sometimes none, of the striated or ice-furrowed stones.

Transported boulders were found in the Braemar district on the top of the hill of Morven, which attains a height of about 3000 feet, and on Ben Uarn More several hundred feet higher, while many were found on the Perthshire hills at elevations exceeding 2000 feet.

Connecting these observations with others made by different geologists in various parts of England, Wales, and Scotland, an opinion was expressed that the drift must have extinguished the land-animals then existing in this country, and that the introduction of the present flora and fauna dates from the close of that period. The denudation of the drift, and the scouring out of the glens and passes, were ascribed in a great measure to the offrushing action of the waters during movements of upheaval, and it was maintained that at the close of these movements this country must have stood higher than at present, and have been connected by land with the Continent of Europe. The more extensive development of land-ice and glaciers was considered to have preceded the marine drifts.

On some Curious Results in the Water Supply afforded by a Spring at Ashey Down, in the Ryde Water-works. *By* E. R. J. Knowles.

The Rev. Dr. Longmuir exhibited a specimen of Fossil Fish sent by the Rev. Mr. Paton of Fettercairn. The basis was carbonate of lime; the black parts, sulphuret of zinc; and the yellow pyrites, which, in their younger days, they were accustomed to call *diamonds* when they occurred in slate. He also presented a communication from the Rev. James Morrison Urquhart, Elgin. The red system of sandstone lay on the one side of Elgin, and the yellow on the other, with the cornstone between, and it was principally near the western side of this middle division that the fossils were found. He had made a flying visit to the place lately, and found that, in a mass of clay extending for several miles, pieces of stone from the size of the fist to that of the head, frequently occurred. These, when broken up by Mr. Morrison in his leisure hours, had afforded the beautiful suite of specimens now on the table. On careful examination they were found to belong to the lower Oolite. Now as the Oolite is above both the Old and the New Red Sandstone, the occurrence of this clay gave them no assistance in determining to which system the reptile was to be referred.

On certain Phenomena attendant on Volcanic Eruptions and Earthquakes in China and Japan. By Dr. Macgowan, *of China.*

On the Age of the Reptilian Sandstones of Morayshire. By John Miller, *F.G.S.*

The author, having referred to the published opinions of Sir R. I. Murchison, declared his unaltered belief in the soundness of the opinion of Sir Roderick, that these sandstones belong to the Old Red Series. He adds a series of observations made by himself with reference to this question.

On some New Fossils from the Old Red Sandstone of Caithness. By John Miller, *F.G.S.*

The author laid before the Association a series of fossils from the flag schists or middle member of the Old Red Sandstone of Caithness, in the neighbourhood of Thurso. The author has found difficulty in determining their true nature. He, however, finally adopts the opinion that they are the outer edges or rims of bell-shaped or trumpet-mouthed marine plants, broken off from the body of the cup or calyx just where we would expect a fracture to take place, where the outward recurvature of the rim or mouth commences, and where it is weakest. In conformity with this hypothesis, we must suppose that they had footstalks or peduncles, and were stationary. Whether these footstalks were long and enabled the bell-shaped calyx to float in the tideway, or whether the calyx occupied a position close to the point of attachment to the sea-bottom, with a long narrow thong-like frond springing from the bottom of the calyx, like the *Himanthalia lorea* in the seas of the present day, it were idle to speculate.

The author described the several examples which were exhibited to the meeting.

No. 1 is a perfect circle of 7 inches in its outer diameter and 3 inches in its inner diameter, the breadth of the ring being 2 inches. As it lies upon the stone it presents a well-relieved convex or ridged surface of black bituminous matter, looking exceedingly like an iron quoit of a large size ; but a close inspection shows that it exists upon the stony ridge as a mere film, conveying the impression that when it originally fell to the bottom of the Devonian sea, it must have sunk into soft mud which filled up its hollow under surface, and thus preserved a most fragile organism which would have been crushed to pieces if it had rested upon a rocky or pebbly sea-bottom.

No. 2 is the cover or impression formed in the stone covering of No. 1, and is therefore a bituminous ring of exactly the same diameters, inner and external; but the ring is of course concave, with a rising up of the matrix in the centre. From its hollow appearance it was called by the workmen who raised it up out of the quarry, "Noah's plate," which had fallen overboard from the Ark, on being washed after dinner. In this specimen also the organic matter is a mere film.

No. 3 is the fragment of a duplicate of No. 1, which must have been a finer specimen in some respects, more flattened, more distinctly marked on the edges, and considerably larger. The bituminous matter in this specimen is slightly tinged with the oxide of iron.

No. 4 is the cover of No. 3; its external diameter is 11 inches, and its inner diameter is 4 inches, the breadth of the ring being 3 inches. Instead of forming a perfect circle, it has a fissure or rent throughout the whole breadth of the ring at right angles to its circumference. This fissure is about half an inch wide, and at first sight one is tempted to think it was an original character necessary for the fulfilment of the functions of the organism; but on comparing its reft circumference with the complete circle formed by Nos. 1 and 2, it may be concluded to be purely accidental. The rising up of the matrix in the centre of this specimen is very prominent, like that in No. 2.

In December of last year, Mr. Salter exhibited at a meeting of the Geological Society of London, some very fine specimens of the curious impressions known to Scotch geologists as "Kelpies' feet," from the micaceous sandstones near Dundee, forming part of the lower member of the Old Red Sandstone in that locality. The organisms now described are not identical with the "Kelpies' feet," which are mere impressions containing no organic matter, and are in general of an oval shape; whereas these specimens, two of them at least, are perfect circles and covered with organic matter.

As we must place these organisms for the present amongst the fossils "*incertæ sedis*," Mr. Miller proposes to name them provisionally *Fucus annulatus*; they were all found in the quarries in the neighbourhood of Thurso.

On New Fossils from the Lower Old Red Sandstone. *By* HUGH MITCHELL, *Craig.*

From a locality previously recorded in Kincardineshire, and from two new localities in Forfarshire, numerous fossils had been gathered, indicating an extensive flora and fauna at the very commencement of the Old Red Sandstone period.

From the dark red flags of Forfar evidence was produced, for the first time, of the presence of life in numerous Crustacean tracks, Annelide burrows, &c.

From a thin layer among the grey flags many new fossils had also been gathered; among the rest a new species of *Acanthodes*, to which Sir P. Egerton has given the name of *Acanthodes antiquus*; and also a new genus, as well as species, to which had been given the name of *Brachyacanthus scutiger*.

Guided by the discoveries in Forfarshire, the other locality had been re-examined, and found to afford, although in a fragmentary state, the same fossils.

On the Geological Structure of the Vicinity of Aberdeen and the North-east of Scotland. By JAMES NICOL, *F.R.S.E., F.G.S., Professor of Natural History in the University of Aberdeen.*

It has been thought that a short sketch of the geology of this locality might interest our visitors from the South. To illustrate this generally, I have had a large copy of that portion of my Geological Map of Scotland prepared. This, of course, does not give minute details, but still I have no hesitation in saying that it is more accurate than any other map, as I have not only corrected it in many parts myself, but have had the use of much material collected by my friend Mr. A. Cruickshank.

Though scarcely needed, it may be mentioned that Scotland consists of three natural geological divisions:—1st. Southern Region of Lower Silurian Rocks of Murchison, or Cambrian of Sedgwick. This region consists of greywacke and clay-slate rising into lofty broad-backed mountains separated by wide valleys, the dales of the old Borderers.

2nd. Central Region of Old Red, Coal, and Trap. This contains only about one-sixth of the surface (5000 square miles), but full two-thirds of the population of Scotland, and a far larger proportion of the mineral wealth and manufactures of the kingdom.

3rd. Northern Region of Primary or Crystalline Strata broken through by Granite, and set in a framework of newer formations. It contains two-thirds of the surface, but little more than one-fourth of the population. It is in this region we are now met, and to one portion of it that I mean specially to direct your attention. The kernel of this whole region is the *Granite*. This forms some of the highest mountains, and some of the lowest land in the district; of the former I may mention

Ben Macdhui (only rivalled in Britain by Ben Nevis) and the Cairngorm mountains on the north of the Dee; and on the south of that river, Loch-na-gar, Mount Keen, Mount Battock, and other giants of the Southern Grampians. These, the principal mountains, are usually round, massive, dome-like, with a deep corry on one side as if formed by the falling in of one-third of the mountain, and thus bounded by lofty, rudely prismatic precipices rising from a dark black tarn in the centre of the hollow. In consequence of decomposition the granite mountains are usually covered with huge feather-bed-like rocks piled up in cairns of rude masonry, and the shelter of the red deer and ptarmigan. The rock in these mountains is rather fine-grained, uniform in structure, and often reddish coloured. It contains cavities in which the rock-crystal or Cairngorm stone, the topaz and the beryl are found. Bennachie, one of the outposts of these mountains on the north-east, though not high and easily accessible, is very interesting. It looks out on the south-west to the loftier ranges of the Grampians, with patches of snow even at the end of summer; and on the north-east over the plains of Buchan—low, undulating, and treeless, but rapidly changing under the industry of the inhabitants from bleak moors to fertile corn-fields.

A large portion of these north-eastern plains, too, consists of granite; in them, however, occupying the lowest, not the highest position, as in the mountains. This fact shows that the granite is the basis on which the strata rest, and hence is exposed where they have been cut away by denudation. A fine section of the granite is seen in the sea-cliffs south from Peterhead, where it is intersected by long narrow gullies and deep caves, in which the restless surge of the North Sea keeps up an incessant tumult. Hence some of the more remarkable of these excavations have got their name of the "Bullers of Buchan."

The rock in this region is red or grey, according to the colour of the felspar. It often contains hornblende, or is a syenite, as in the tract to the north of Huntly, and in other places again becomes almost a fine-grained greenstone or diorite. This diversity of mineral character proves that the granite is not all of one period of formation. The veins of granite in the granite itself show this even more clearly. These are beautifully seen in Rubislaw quarry, close to the town, where there is one very remarkable vein of coarse granite composed of very large twin crystals of orthoclase-felspar, and mica in a basis of quartz along with long broken prisms of schorl, Davidsonite or impure beryl, and garnets. The quartz in this vein is also remarkable for numerous cavities enclosing fluids.

Of the stratified rocks, the first, *gneiss*, covers a wide extent in Aberdeenshire, and generally in close proximity to or resting on the granite. It is thus seen in the valley of the Dee above Braemar, reposing on the granite in thin even beds at a low angle, and apparently undisturbed by the inferior igneous rock. In many parts of the low country the same relation occurs, the gneiss often forming the hills, the granite the intervening valleys. But in other cases, as in the hills north of Ballater, the two formations are seen side by side. The gneiss in many localities is full of granite veins; but whether these belong to the great mass of granite or are of a different age, is not easily determined; and the question seems never to have been fully or fairly worked out. Such veins are well seen on the coast to the south of this city, especially near Girdleness and the Cove, and also in many parts of the mountain chain on the south side of the Dee. Veins of felspar-porphyry, and of trap, are known in the gneiss on the same coast and in many other localities.

The gneiss is usually the common variety of quartz, felspar, and mica. But varieties with hornblende passing into hornblende-slate are also common. The latter are well seen in the hills along Glen Muic and up to the top of Morven. The beds of gneiss are seldom flat or even, more often highly contorted.

In the Braemar district the gneiss is covered by beds of limestone and quartzite—the latter perhaps only a variety of the gneiss. It often contains much magnetite, apparently replacing the mica. Indeed iron, both as the oxides and the pyrites, is very common in all these rocks; strongly impregnating many of the springs, and finding its way into the sands of the rivers and of the sea-shore. From the Cairngorm mountains great ridges of quartzite run north into Banffshire and to the coast near Cullen. In some places in this region it appears to lie below the mica-slate, but their exact relation is obscure. In other parts of the low country, as in Mormond Hill, the quartzite rests on the gneiss.

Mica-slate in Scotland is most common in the South-west Grampians; but in this district it becomes attenuated to a very narrow zone. In the Glenshee and Stonehaven sections the mica-slate appears to lie below the gneiss, and not over it, as usually represented. There are great tracts of mica-slate also in the north-west, between the Spey and the Deveron, where it is intermixed with gneiss and clay-slate, but the relations of the deposits are little understood. It often contains garnets, more rarely Andalusite, and some other minerals.

Clay-slate also covers a considerable space in this district, chiefly to the south of Banff and the Troup Head. It is quarried in several places for roofing-slates, as near the Troup Head, in the Foudland Hills, and near Gartly. These slates are wrought on lines of cleavage, the bedding being in general scarcely perceptible. It has been said that fossils—graptolites—occur in this rock; but there is no foundation for this statement. I formerly described these clay-slates as probably Silurian; but this is only a theory, and as the clay-slate in the Southern Grampians appears to dip north below the mica-slate, this view now requires confirmation. In Glenshee a curious series of black carbonaceous slates, containing graphite like those of Easdale, occur. Graphite is also found in other parts of this region, in the metamorphic strata—a most important fact in reference to the theory of these rocks.

The *Old Red Sandstone* chiefly occurs on the outskirts of the region we are considering. The principal mass within it runs south from Gamrie—a locality well known for its nodules with fossil fish. Another isolated, but interesting portion occurs round the ancient Castle of Kildrummy, in which impressions of plants have been found. A curious mass of conglomerate at the Old Bridge of Don probably belongs to the same deposit. On the southern limit of the map, the Great Red Sandstone formation of Strathmore begins, and is well seen in huge beds of red sandstone and conglomerate near Dunnottar. The conglomerate must be regarded as marking rather the shore-lines, or certain peculiar local conditions, than any particular zone in the formation.

At the other extremity of the map on the Spey, the Morayshire deposits begin with numerous fishes at Tynet Burn, Dipple, &c. Still further west are the beds with reptilian remains at Elgin, probably in the upper Old Red, or some newer formation, but beyond the limits of this paper.

Higher deposits are only known in fragments. Such is the portion of lias near Turriff, perhaps *in situ*; but other masses of clay with lias fossils, as near Banff, are more probably drifted. So also the greensand and chalk flints, spread over the rising ground from Peterhead to Cruden—noticed and collected in 1834 by the late Dr. Knight of this University—are apparently detrital masses. Their number, however, and state of preservation show that strata of this age probably once existed here *in situ*, and perhaps they may still occur below the waters of the North Sea. I formerly noticed the analogy of these deposits to those in the south of Sweden, where lias rests on gneiss, and is covered by chalk; but Flamborough Head is the nearest point where the chalk is now known *in situ*.

Last of all are the great detrital masses of the *Drift* or *Boulder-clay*. This forms two very marked divisions, evidently formed under very opposite conditions of the land. 1st. The lower boulder-clay composed of thick beds of firm brown or grey clay and full of large striated stones, some of them several feet or yards in diameter, and evidently deposited in an arctic sea round the shores of an ice-clad land rapidly sinking in the waters. Glaciers, as the striæ they have left on the rocks testify, must then have covered our mountains, and floating icebergs filled our ocean. Above this deposit are:—2nd. Loose, distinctly stratified sands and gravels with rounded water-worn stones. These are clearly a portion of the lower masses reconstructed as the land, now freed from ice, rose gradually above the waters. The brick clays, some blue, some red, are again only the finer materials washed out in this process, and laid down in gulfs and bays and the quieter parts of the sea along the coast. They contain arctic shells—showing that the climate was still cold; and also at Clay-hills, in the very city, star-fish (*Ophiura*), bones of fish like the cod or haddock; and full 30 feet below the present surface bones of a small duck. They are well seen at Belhelvie, Old Aberdeen, and Torrie, but occur in many other localities. All along the south coast too, the fishermen dredge up, attached to the large mussel by its byssus, valves of the *Pecten islandicus* and the small *Leda oblonga*, shown by their colour to have been imbedded in similar red clays.

In the peat-bogs we have remains of even a more recent period, but little anterior to our own. In them are found skulls with gigantic horns and huge bones of the old Urus. Two fine specimens of these skulls in the Museum—one from Belhelvie, another from Caithness—show the wide range of this noble species in former times. And here the proper geologic history of the district ends.

On the Relations of the Gneiss, Red Sandstone, and Quartzite in the North-West Highlands. By JAMES NICOL, *F.R.S.E., F.G.S., Professor of Natural History in the University of Aberdeen.*

The author expressed his reluctance and regret at appearing in opposition to his distingushed friend, Sir R. I. Murchison. After the eloquent lecture which they had listened to on Friday evening, he would willingly have remained silent on the points of difference. But last year, at Leeds, Sir R. Murchison had challenged him to discuss the question here, and this challenge he could not decline. The question is one of far too much importance, not only in the geology of Scotland, but in general theoretical geology, to be left undecided.

Sir Roderick said the other night that he had visited this region four times in order to examine this question. Prof. Nicol had also spent a considerable portion of four summers investigating these rocks, and had traversed the whole line of junction from Cape Wrath and Loch Erriboll to the Sound of Sleat in Skye, and examined the strata from the wilds of Lewis in the far west, to the interior of Sutherland and Ross on the east. He might thus claim some knowledge of the formation, and stated no facts in this paper except such as he had observed. For the distribution of the rocks he referred to his recent Geological Map of Scotland, in which the red sandstone of the west was first separated from the undoubted Old Red Sandstone on the east coast.

There was no difference of opinion between Sir R. Murchison and himself in regard to the first steps in the series. Both were at one in regard to the order established in Prof. Nicol's paper of 1856, of—1st, Gneiss, covered unconformably by, 2nd, Red Sandstone, and this by, 3rd, Quartzite, and, 4th, Limestone. But here they diverge—Sir R. Murchison affirming that there is another higher quartzite and limestone overlaid conformably by mica-slate and gneiss, whilst Prof. Nicol states that there is here a line of fracture bringing up anew the lower beds of the old metamorphic formation. In proof of this he exhibited and described various sections. The first, of Durness, showed on the west side in Far Out Head, mica-slate identical with that on the Kyle of Tongue, then fragments of limestone, interrupted by mica-slate and serpentine, then again limestone and quartzite, all separated from each other by N. and S. faults and raised up by an axis of granitic gneiss, and then on Loch Erriboll the quartzite and limestone, dipping west from another igneous axis, throwing off beds of talc and mica-slates like those of Far Out Head to the east. He showed also another section in this region, in which the supposed overlying gneiss was proved to be a felspar porphyry.

He next stated that the same relations existed at Craig na Feolin, and on Loch More, where the rocks described by former observers as overlying gneiss were in reality an intrusive rock; whilst the great mass 800 or 1000 feet thick of quartzite seen in Arkle on the north of Loch Stack, on the south of that Lake was represented only by a few beds, and did not regain its dimensions till we reached Assynt, where it has escaped denudation. The Assynt section he also showed had been greatly misunderstood, the limestone of Stronchrubie being troughed by the quartzite of Ben More and not dipping under it, whilst great masses of igneous rocks had been wholly overlooked.

He then explained a section of Coolmore and Craig-an-Cnockan, in which the quartzite covered by the limestone was brought side by side with the gneiss on the east by a fault with interposed igneous rocks. Referring to his sections on Loch Broom formerly published, and to the Loch Maree section described at the last meeting of the Association, he proceeded to explain a large section of the Gair-loch and Loch Torridon Mountains, in which the true structure of the country was well shown. In this the quartzite was seen not only overlying but apparently alternating with, and dipping under the red sandstone no less than five times in a single mountain, the whole, however, as distinctly seen in the naked precipices, being produced by repeated slips and fractures with enormous lateral pressure. At the eastern extremity of the section, the quartzite was brought into contact with the gneiss along a nearly vertical line of fault, but without dipping under it, and the same relation was shown in another section from the Loch Carron district.

These sections, to which many others might be added, abundantly prove that there is here no continuous, conformable, upward succession, but that this portion of the Highlands is made up of a series of fragments of strata brought side by side by enormous slips and powerful lateral pressure. This lateral compression was shown in the contorted lamination of hand specimens of the rocks from the two sides of the fault. This pressure may in some cases have caused an apparent overlap of the lower beds on the higher, though in the whole line of junction, 100 miles in extent, Prof. Nicol has never observed any clear case of this nature. But that such cases could only be mere accidents is proved by many facts. The superposition of the red sandstone to the gneiss can be observed over miles and miles of country; that of the quartzite to the red sandstone is no less distinct, being readily traced by the eye from mountain top to mountain top, from valley to valley; and again the limestone, though a small formation, everywhere clearly reposes on the quartzite—at Durness, Erriboll, Loch More, Assynt, Ullapool, Loch Maree, Loch Keeshorn. But how is it with the next step in the supposed series? Nowhere is an overlap of more than a few feet or yards even said to be seen, though the supposed overlying rocks extend more than thirty miles to the east, the underlying fully as much to the west. The fact, too, that the eastern gneiss is brought into contact in one place with the limestone, in another with the quartzite, in a third with the red sandstone, according to the amount of denudation, and all within a few miles, prove that the junction is along a line of fault, and is wholly inexplicable on the supposition of conformable upward succession.

The mineral character of the eastern gneiss has also been referred to, as proving it a newer rock. But this is founded on the unproved assumption that the coarse-grained gneiss is older than the fine-grained, whereas the reverse is nearer the truth. Prof. Nicol stated that he had formerly shown that in the Southern Grampians the clay-slate and mica-slate were probably older than the gneiss, and he believed that the same relations existed in this north-west part of Scotland. Where the greatest upthrow of the eastern gneiss has taken place, we have clay-slate brought into contact with the quartzite, and covered successively by mica-slate and true granitic gneiss. Where the upthrow is less, only the mica-slate and gneiss are seen, or even the gneiss alone in contact with the quartzite. He therefore affirmed that we have in this north-west region of Scotland a line of fracture analogous to that along the southern flank of the Grampians, and not inferior to it in extent and influence on the physical structure of the country.

On some new Boreal forms—the nearly perfect skeletons of Surf and Eider Ducks, Oidema *and* Somateria—*accompanying the remains of Seals, from the Pleistocene Brick-clays of Stratheden, Fifeshire; nine miles inland, and* 150 *feet above medium tide-level. By* D. Page, *F.G.S.*

On the Structure, Affinities, and Geological Range of the Crustacean Family Eurypteridæ, as embracing the genera Eurypterus, Pterygotus, Stylonurus, Eidothea, *and other doubtful Eurypterites from the Silurian, Devonian, and Carboniferous strata of Britain, Russia, and North America. By* D. Page, *F.G.S.*

On Fossil Fish, new to the Old Red Sandstone of Caithness. By C. W. Peach.

The first mentioned was a small but very beautiful *Acanthodus* from the quarry of the Earl of Caithness near Barrogill. He turned it up about four years ago. The species is not yet decided. It is, however, a curious fact that the same genus should have been met with in Forfarshire and Caithness about the same time; and another from Thurso, much smaller, with strong and long spines, and as if clothed with a thick skin. This and the three next are not named. The great interest attaching to the next arises from its having a stout vertebral column running from the head to the tail, and also strong internal supports to the fin rays. Whether these and the vertebral column are of bone is still an open question. The scales are large and coarse: it is about ten inches in length, and came from the red and blistered sandstones near John O'Groat's. There is an especial interest attaching to this fish, for Hugh Miller says in his 'Old Red Sandstone':—"In no case, however, have I succeeded in finding a single joint of the vertebral column, or the trace of a single internal ray." This has not been contradicted in any of his works. Mr. Peach mentioned that he had at different times found in Caithness several other fishes with vertebral columns, all much smaller than the above, and shown principally towards the tail. The next was taken from the impure limestone at the south head of Wick; he also got it in the bed of the river at Halkirk, and in the limestone of Balagill, near Strathy in Sunderland. The last produced is peculiar, differing from both Dipterus and Diplopterus, in having a narrower but stouter snout, and the front part of the upper jaw armed with short conical teeth, the eye orbits nearer together and placed on the upper part of the head.

On the Ossiferous Fissures at Oreston near Plymouth. *By* W. Pengelly, *F.G.S.*

Mr. Pengelly commenced this communication by reminding the Section that he had called attention, during the meeting at Leeds, to some of the results of the exploration, then in progress, of the cavern which, early in the year 1858, had been discovered on Windmill Hill, at Brixham, in Devonshire; and remarked that though, perhaps, none of the facts then communicated were new to science, the circumstances of the case gave them a peculiar value, as being perfectly reliable and unquestionably good in evidence, and as furnishing a test or measure of the credibility of, at least, some of the facts on record in connexion with other caverns.

After stating that the case to which he had now to call attention had no such claims, that the facts, such as they were, had come into his possession almost by accident and mainly from the quarrymen, and that no attempt had been made to direct or control the excavation, the author stated that when Mr. Whidby engaged to superintend that most arduous undertaking, the Plymouth Breakwater, Sir Joseph Banks requested him to examine narrowly any caverns he might meet with in the rock, and have the bones or any other fossil remains that were met with carefully preserved*. The Oreston quarries were opened to furnish material for the Breakwater on August 7th, 1812; in November 1816 Mr. Whidby sent up to Sir Joseph Banks his first consignment of bones, with a statement that "they had been found in a cavern in the solid limestone rock." The fossils were described by Sir Everard Home in a paper read before the Royal Society, and published in the Philosophical Transactions for 1817; in November 1820 Mr. Whidby discovered a second ossiferous cavern, and sent up the bones found in it to Sir Everard Home, who described them in a paper read before the Royal Society, and published in the Philosophical Transactions for 1821; in 1822 a third bone-cave was found at Oreston; the fossils found in it were forwarded to Sir John Barrow, and described by Mr. Clift in a paper which was read before the Royal Society, and published in the Philosophical Transactions for 1823.

On the authority of Professor Owen, the ossiferous caverns and fissures of Devonshire have yielded remains of the following species of mammals, namely:—

EXTINCT SPECIES.

Ursus priscus.............		Ke. O.
Ursus spelæus............	Great Cave Bear.	Ke. O. Ki. G. M. D.
Hyæna spelæa............	Cave Hyæna.	Ke. O. Ki. G. M. D.
Felis spelæa..............	Great Cave Lion.	Ke. O. Ki. M.
Machairodus latidens......		Ke.
Lagomys spelæa..........	Cave Pika.	Ke.
Elephas primigenius......	Mammoth.	Ke. Ki. M.
Rhinoceros tichorhinus....	Tichorhine Two-horned Rhinoceros.	Ke. O. Ki.
Equus fossilis............	Fossil Horse.	Ke. O. Ki. G. M.
Equus plicidens..........		O.

* Philosophical Transactions, 1817, p. 176.

Asinus fossilis............Fossil Ass or Zebra. O.
Hippopotamus major......Large Fossil Hippopotamus. Ke. Ki. D.
Megaceros Hibernicus.....Gigantic Irish Deer. Ke.
Strongyloceros spelæus ....Gigantic Round-antlered Deer. Ke.
Cervus Bucklandi ....Buckland's Deer. Devon. Ki.
Bison minor .... O.
Bos longifrons............Long-fronted Ox. O. Ki.

RECENT SPECIES.

Rhinolophus ferrum-equinum Great Horseshoe Bat. Ke.
Sorex vulgaris............Shrew. Ke.
Meles taxus..............Badger. Ke. B.
Putorius vulgaris ....Polecat. B.
Putorius ermineus ....Stoat. Ke. B. O.? Ki.
Canis lupus..............Wolf. Ke. O. K. G.?
Vulpes vulgaris ....Fox. Ke. O.
Felis catus ....Wild-cat. Ke.
Arvicola amphibia ....Water-vole. Ke. B. O.? Ki.
Arvicola agrestis ....Field-vole. Ke. Ki.
Arvicola pratensis ....Bank-vole. Ke.
Lepus variabilis ....Norway Hare. Ke. Ki.
Lepus cuniculus ....Rabbit. Ke. B. Ki.
Cervus elaphus ....Red-deer. Ke. Ki.
Cervus tarandus..........Rein-deer. B.
Cervus capreolus..........Roe-deer. Devon. O.

In the above list, initials are appended to the names for the purpose of showing in what caverns the fossils are recorded to have been found: thus, Ke, Kent's Hole, Torquay; B, Berry Head, Ash Hole; O, Oreston; Ki, Kirkdale; G, Gower; M, the Mendip Caves; and D, the Caves on Durdham Down, near Bristol.

In all there are thirty-three species, of which seventeen are extinct, and sixteen still exist, a few of the latter being locally extinct. Three additional species have been found in other British caves, but no traces of them seem hitherto to have been met with in Devonshire, namely, the Common Mouse, found in the Kirkdale Cavern; the Wild Hog, found in the caves of the Mendip Hills, and the Fallow Deer, found, according to some authorities, in the caves of Kirkdale and Paviland. Fourteen or perhaps sixteen species have been found at Oreston. Two species, *Cervus Bucklandi* and *Cervus capreolus*, are assigned to Devonshire without the cavern in which they were found being named. Hence nineteen or seventeen, as the case may be, of the Devonshire list are unrepresented in the Oreston series. The following species are, according to the present state of our knowledge, peculiar to Oreston, namely, *Asinus fossilis*, *Bison minor*, *Bos longifrons*—all extinct forms.

After the lapse of thirty-six years since Mr. Whidby's last discovery of fossils at Oreston, the quarrymen have found other caverns and fissures rich in bones, a great number of which have been purchased by the author, and by him handed over to the British Museum. The new cavern was discovered towards the close of 1858; and from information obtained from an old quarryman, who pointed out the direction of Mr. Whidby's caverns (all of which had been destroyed by the ordinary quarrying operations), it appeared that the new one was in the same line,—as if the various caverns had been so many enlarged portions of one and the same original line of fracture.

The new cavern was about 90 feet long, and extended in a direction from north-north-east to south-south-west, or very nearly that of the dip of the limestone beds. It commenced about 8 feet below the top of the cliff and continued to its base, and was about 52 feet high. At the top it was about 2 feet wide, gradually increasing downwards, and reaching a width of 10 feet at bottom. The first or upper 8 feet were occupied with what the workmen call "gravel," which consisted of angular portions of the adjacent limestone, mixed with a comparatively small amount of sand. This limestone debris varied in dimensions from fragments of the size of hazel nuts to pieces ten pounds in weight. This accumulation was entirely free from stalagmite, and was in no part cemented. No traces of fossils were found in it. The next 32 feet in depth were occupied with materials similar to those just mentioned (the sand being somewhat more abundant), with the addition of a tough, dark, unctuous clay. Between this mass of heterogeneous materials and the western, or what may be called the river-wall of the cavern, occurred a nearly vertical brecciated plate or dyke, which the workmen denominated "Callis;" extremely tough, and quite as difficult to work as the compact limestone itself. It may be described as an approximately vertical plate of stalactitic carbonate of lime, containing, at by no means very wide intervals, masses of breccia, made up of the materials just named as composing the accumulation in contact with and on its eastern or hill side, and cemented together by carbonate of lime. Some of these masses measured fully a yard cube, but the general thickness of the Callis was about 2 feet. This was the bone-bed, that is to say the bones were found alike in the *Callis* and in the mass of heterogeneous materials beside it, in the cemented and uncemented portions of the bed. They were found alike at all heights or levels, in the lumps of breccia, in the pure stalagmite between them, and in the looser and less coherent portion of the accumulation; thereby suggesting that the cavern was slowly and gradually filled with limestone debris detached from the rock in which the cavern occurred, with sand transported, at least, some distance, and with mud; not each in definitely successive periods, but together; with occasional pauses or periods of cessation; the proof of such pauses being the frequent presence of the portions of pure stalagmite separating series of brecciated masses made up of angular limestones, clay, and sand, lying one above another in the same nearly vertical plane. The rapidity of the infilling, and hence the time required for the process, seem of necessity to be measured by the rate of deposition of the stalagmite, whatever that may have been. It appears, too, that throughout the entire period—be it long or short—required for and represented by the accumulation of the materials under consideration—alike during the periods of active and of tardy accumulation—bones of various animals were introduced and inhumed, and that there was no marked cessation in this part of the work, since the bones were found as frequently in the pure stalagmite as elsewhere. The bones were frequently in a very fragmentary condition, as if broken by fragments of rock falling on them.

A somewhat considerable number of clay balls, generally ellipsoidal, and varying from an inch and a half to two and a half in greatest diameter, were found in the clay throughout the bone-bed, but not above or below it.

Beneath the materials just described, occurs a bed of dark, very tough, unctuous clay, known to be 12 feet thick, but perhaps more, as its base has not been reached.

The workmen positively assert that the roof of the cavern, 8 feet in thickness, was of sound unbroken limestone, and that the stones and other materials could not have fallen in from above; but unfortunately they with equal positiveness affirm that there was no external opening whatever, either vertical, terminal, or lateral; the author, however, is of opinion that there is ample reason for believing that the cavern originally communicated with the surface by an opening sufficiently wide to allow the passage of all its contents, and that it was thus filled; but whether animals fell, or were dragged in, or whether the bones found there were wholly or partially the disjoined remnants of dead animals washed in, he would not undertake to say.

In conclusion Mr. Pengelly said, "Without the pale of philosophy exists a many-motived curiosity on this subject, quite as powerful, if not so intelligent or manageable, as that which leads, yet is under the guidance of science. Recent discoveries have made it not a question of exploration now or at some future time; the alternatives are prompt systematic investigation, or the abandoning of our caverns to be ransacked by fossil dealers."

On Slickensides. By JOHN PRICE, *M.A.*

This communication (in the absence of the author read by J. J. Walker, M.A.) included in the term "Slickensides" every mineral surface which, apart from crystallization, exhibits an extraordinary degree of polish. The author invited the attention of observers to it, and mentioned his having observed it *in situ* only in the neighbourhood of Birkenhead, and at Llysfaen near Abergele, and a few other localities. In all these instances the author had observed *two* pairs of polished surfaces, sometimes within a half-inch, sometimes two feet from another, the intermediate space being occupied by rock more or less altered. These surfaces always exhibit *striæ* more or less inclined. The author concluded by proposing several questions with respect to the phenomenon, with a view to obtain light on it.

On a Fragment of Pottery found in Superficial Deposits in Paris. By M. A. Radiguel.

On the Origin of "Cone-in-Cone." By H. C. Sorby, *F.R.S. &c.*

Cone-in-Cone is met with in so many stratified rocks, that most geologists must be familiar with its general characters, though no one appears to have thoroughly investigated it, or to have given any very satisfactory explanation of its origin. The cones often occur in bands parallel to the stratification of the rock, their apices starting from a well-defined plane; and, after extending upwards or downwards for a greater or less distance, with their axes perpendicular to the plane of the stratification, they end in bases parallel to it, but not all at the same exact level, some standing up above the general surface. They are not perfect cones, but are of such forms as would result from the varied interference of surrounding cones, and from the development of others within their own substance. On examining thin, transparent sections with a low magnifying power, under polarized light, the author had been able to ascertain that this peculiar structure is intimately connected with some kinds of oolitic grains. In the formation of the most abundant variety of oolitic grains small prismatic crystals of more or less pure carbonate of lime were deposited round a nucleus in nearly the same amount on all sides, so as to give rise to irregular ovoid bodies; whereas, in the formation of cone-in-cone, very similar crystals were deposited almost entirely on one side, along the line of the axis of the cones, in such a fan-shaped manner as to give rise to their conical shape. In the thin sections of some specimens every connecting link between imperfect oolitic grains and genuine cones can be seen to great advantage with polarized light. The growth of the cones did not however proceed without interruption, for other smaller fan-shaped groups were developed within the larger; and thus by the mutual interference of contiguous groups and of others contained within themselves, there was formed a mass of irregular cones enclosing other cones. The author therefore concludes that this structure is one of the peculiar forms of concretions, formed after the deposition of the rock in which they occur, by the crystallization of the carbonate of lime and other isomorphous bases.

On some Fishes and Tracks from the Passage Rocks and from the Old Red Sandstone of Herefordshire. By the Rev. W. S. Symonds, *M.A., F.G.S.*

I have little to add to the Table of Sir Roderick Murchison, published in the Quarterly Journal of the Geological Society, giving a synoptical view of the Old Red Sandstone of Britain and the Devonian rocks of Devonshire and the continent; with the list of fossil fishes of the Old Red ichthyolites of England, Scotland and Russia. The fishes of the Upper Ludlow rock can no longer be denominated as the first of their class, for that most ancient known fish, the *Pteraspis Ludensis*, has been detected both in the *Lower* as well as the Upper Ludlow rock.

It has been said that "Life is governed by new conditions, and new conditions imply new races;" and I suspect that when more of the leaves of the massive volume of historic geology are cut and deciphered, it will be found that whole tribes and races of animals have been extinguished by geologists before they were extinguished by Nature, while many were called into existence, and flourished for ages, though as yet they have not been disinterred from their mausoleum of rock.

The *Pteraspis Ludensis* is known in the Lower Ludlow rock of Murchison, and has been found in the Upper Ludlow deposits *below* the bone-bed; while *Pteraspis Banksii*, which occurs in the passage beds that link the Upper Silurians with the Lower Old Red, appears to connect the passage rocks with the zone of the Old Red charged with abundant remains of *P. Lloydii*, *P. rostratus*, and *Cephalaspis Lyellii*.

The *Auchenaspis Salteri*, Egerton, is a remarkable little Cephalaspidian fish, which has hitherto been detected only in the *grey* passage beds of Ludlow and Ledbury. I have for your examination an interesting specimen of this fish from the upper limits of the grey beds which pass into red sandstones higher in stratigraphical position than the true Auchenaspis grits, thus furnishing a very unequivocal proof of a fossil fish passing the physical limits of its assigned position, and caught, *flagrante delicto*, going upwards into beds which contain other species of *Pteraspis* and *Cephalaspis* than those with which the truant Auchenaspis should have associated.

I have also the pleasure of introducing to your notice a head of Cephalaspis from beds at the base of the grey beds which contain the *Auchenaspis Salteri*, and these beds pass into red sandstones with Silurian shells, and from them conformably into the Downton sandstones which rest at the summit of the Silurian System. There are also among the specimens I now exhibit some good examples of the lower Old Red plants.

The tracks of the lower Old Red Sandstone, to which I would call your attention, are developed on a large slab measuring 3 feet 2 inches by 2 feet 4 inches. That well-known geologist, the late Rev. T. T. Lewis of Bristow, the friend and coadjutor of Sir Roderick Murchison, when on a visit to the quarries of Puddlestone near Leominster, saw this slab resting *in situ* on the upper working beds of the quarry. He had it carefully quarried and conveyed to Bristow. A few days before his death he expressed a wish that I might become the possessor, in memory of many happy days we had passed together among the rocks of the Old Red and the hills and vales of Herefordshire. As an instance of the ripple-marking of waves that have for myriads of ages ceased to flow, this Old Red slab would be a treasure to the geologist; but another feature presents itself, for we find that some animal has wended its way directly across the ripple-marks, leaving the impressions of its movements as distinctly marked as the human foot-tracks of the limestone of Guadaloupe. These tracks are $1\frac{1}{4}$ inch in length; and not only is the trail preserved, but even the folding of the sandy mud, by the indentation of a fish's defence, or a crustacean's tail is preserved, and the raised surface of the old sea-shore, or littoral deposit, stands out in bold relief. The stereoscope gives a slight idea of the remarkable indentations of this slab. Since I came into this room I have met with a brother geologist, the Rev. Mr. Smith of Peterhead, who recognizes these tracks as appearing in the Old Red Sandstone of Rhyme, Aberdeenshire.

On the Rocks and Minerals in the Property of the Marquis of Breadalbane. *By* C. G. Thost.

The district described in this paper extends for 100 miles from east to west. The rocks are chiefly mica-slate, but talc-slate, chlorite slate, and hornblende rocks are also very common in large masses, and in the north and north-west gneiss and granite. Calcareous varieties of the mica-slate also occur, sometimes in lenticular masses of nearly pure limestone with 90 per cent. of carbonate of lime. Clay-slate likewise appears very high up on the north side of Ben Lawers. The strike of the rocks is generally E. and W.; their dip low and various, especially where affected by the intrusive rocks or the ridges and veins of quartz. The igneous rocks are chiefly porphyries and greenstones, well seen at the Tomnadashan Mines on the south side of Loch Tay. In that place the greenstones are evidently the older rock as broken up by the porphyry, which has also introduced the mineral ores. These are seen in it everywhere, but in the greenstone only where in contact with the porphyry. These ores are, silver ore, copper pyrites, grey copper ore, iron pyrites, and molybdena. They are most abundant near the greenstone, and often surround the fragments as if the fluid mass had cooled sooner in these places, and thus collected the metallic matters in more abundance. Near the richer deposits of ore, other minerals, as calc-spar, in scalenohedron macles, dolomite, quartz, and sulphate of barytes, also occur. Mines presenting similar conditions are known at Ardtallanaig, about a mile distant, and in many other places. Indeed the hills east of Loch Tay near Taymouth literally swarm with veins of copper pyrites, iron pyrites, and galena.

A serpentine vein near the upper end of Loch Tay contains chromite, and near it the mica-slate has the mica replaced by graphite in considerable beds.

At Tyndrum, where the mines have been longest wrought, there are three veins. Besides quartz and the common spars, these veins contain copper pyrites, zinc-blende, cobalt ore, titanitic iron, and iron pyrites. In one of the veins fragments of mica-slate occur. In this neighbourhood also a very remarkable vein of quartz is seen, running for miles like a high wall over hill and vale. It appears in many places to have disturbed the associated strata.

In conclusion, the author remarks that it is remarkable that Scotland should possess so few mines. In this region the ores are very wide-spread, though only in small quantity. Most of the discoveries have been made by the intelligent zeal of the Marquis of Breadalbane, who takes a great interest in geological researches.

On some Old Red Sandstone Fossils. By J. WYLLIE.

BOTANY AND ZOOLOGY, INCLUDING PHYSIOLOGY.

Address by Sir WILLIAM JARDINE, *Bart., President of the Section.*

ALTHOUGH it has not been usual to occupy much time at the opening of the Sectional Meetings, and in the address of last evening by our Royal President you were informed of the general objects of the British Association, still it may be right that I should remind the Section that our presence in this northern locality and the peculiar and gratifying circumstances under which we have now met, are due to the cultivation of pure and rigid science, and to the practical application of its principles.

In the early days of the British Association the circumstances which were considered desirable, nay, in some instances were thought indispensable for a successful meeting, were a populous neighbourhood connected in some way with learning, or with commerce or manufactures, and to which there was an easy and rapid access; thus the universities, capitals, and large towns of the south were an early choice; and in 1833, 1834, or 1835, Aberdeen, as a future place of meeting, never entered into the thoughts of the most devoted extender of science. The inhabitants of this great city may look back with satisfaction upon their own enterprise, which, by the application of science, has so much modified and reduced time and distance and expense, that hundreds of persons are enabled this day to meet together here and commune with each other over the mighty agents which God has placed within their power. To the same causes are we indebted for the proud position the British Association now holds: Her Majesty and her Royal Consort give us their countenance and support, while Science enables them to communicate with London and the world simply and freely, and thus it is that the peace of the world will be best preserved; for while on the one hand mind and science are engaged in continuing and perfecting engines of destruction, of range and power far beyond what has ever been conceived possible, they are at the same time widening and expanding the means of intercommunication between the various nations of the world. I think, then, under these circumstances, I am entitled to offer my congratulations upon our meeting in this northern position, and to express my satisfaction at again joining many old friends and associates; and if a graver feeling sometimes steals over at the absence of those whom we have been wont to meet, it is softened and brightened by the sight of the many new members that have come I trust to assist and take part in our discussions.

Since we met last year in Leeds, Zoology and Botany I may say have steadily advanced. In Great Britain and Ireland the works which have been commenced in former years—some have been finished, and others go on with their wonted energy. The fine volumes incident to the Government expeditions, brought out at the public expense, and under charge of the Lords Commissioners of the Admiralty, have been mostly completed, with one exception, to which, we trust, the attention of Government will be directed by some of our scientific friends in Parliament; it is the Zoology of the Expedition of the 'Erebus' and 'Terror' from 1839 to 1843. This was commenced in 1844, and after a period of fifteen years, yet remains unfinished. The contributions to the Natural History of Labuan and the adjacent coasts of Borneo, by Mr. Motley and

Mr. Dillwyn, so beautifully commenced a few years since, and illustrating a Fauna little known, has not been continued, and will, I much regret, cease to be so under its original authors; for, in the fearful massacre that took place at Kalangan on the 1st of May last, Mr. Motley and his family were the first to fall victims to the rage of the natives. This unhappy loss will be a serious one for science. Mr. Motley laboured hard in our particular walks; but being chief engineer of the coal-mines in the eastern division of Borneo, he had turned his mind to geology, and at the time of his death was preparing a paper for this very Meeting upon the coal of those countries, and upon 'The Progress and Growth of New Coal Formations now preparing for Future Ages.' It may be recollected that among the grants of money appropriated at our last Meeting to Section D, there was one to assist Mr. Eyton to illustrate the comparative osteology of birds, to which subject he has particularly directed his attention. Two beautiful numbers have already appeared, and the third is ready for publication. The periodicals devoted to zoology and botany continue to be well conducted. In these and in the Transactions of Learned Societies, much facility and encouragement are given to the publication of valuable memoirs; and I may mention that in one branch which has not yet maintained a periodical for itself, an experiment is being tried in Mr. Sclater's 'Ibis,' of which the first year's numbers will be completed in October. In Ireland, the Rev. C. O'Meara's works on 'The Reproduction of the Diatomaceæ' hold a first place. Mr. Archer's papers 'On the Desmidieæ' are also able. In Zoology, marine life has been most advanced by Dr. Kinahan, Profs. Green and W. King; while in the Dublin University a lectureship in zoology has been founded, and shows its value by being well attended. The importance of Publishing Societies has been generally acknowledged. Many of us are members of the Ray Society, devoted to furthering the objects of our Section; and it gives me pleasure to lay before you Prof. Huxley's beautiful volume on 'Oceanic Hydrozoa,' observed during the voyage of H.M.S. 'Rattlesnake,' now ready for subscribers; and also the drawings and plates of Mr. Blackwall's volume on 'Spiders,' also far advanced. The members of our Learned Societies have occasionally founded medals or prizes for the encouragement of men of science. You will see presented to Sir R. Murchison during this Meeting the medal founded by Sir T. Brisbane, President of the Royal Society of Edinburgh; and the late Dr. Patrick Neil founded another medal, which has been this year awarded to a botanical work of rare excellence, and beautifully illustrated, 'The Reproductive Organs of Lichens,' by Dr. J. Lindsay.

The condition of our Public Museums is a very important subject. The discussions upon the accommodation in our noble national collections, and of the propriety of the separation of the Literary and Art Departments from the Physical will, I have no doubt, bring out results favourable to both. Every facility for study, as far as circumstances will permit, is already given by the courtesy and attention of the officers; but there is nevertheless a want of room and of suitable accommodations to enable naturalists to compare specimens and solve questions, which their own or other limited collections do not afford the means of doing. One great and important feature is the arrangement and cataloguing of these collections. The officers of the British Museum have worked hard in these departments, and its Catalogues now reach to a numerous and valuable series of volumes. Some of these are well illustrated, while others are almost monographs. This year Dr. Gray has devoted one to a portion of the Batrachians or Frogs, and Mr. F. Smith has published a capital part 'On the Fossorial Hymenoptera.' The University Museum of Edinburgh is one of great value, and besides possessing the rich mineralogical collection made by its late able Professor, Jameson, it gained by purchase the entire zoological collection of the late M. Dufresne of Paris, in which are many of the type-specimens mentioned and described in the zoological works published at the end of the last and beginning of the present century. The formation of a Museum of Technology under Prof. George Wilson will, I trust, improve the condition of this part of the University, but at present the accommodation and income allowed for museum purposes are not nearly sufficient, and it is impossible for the Regius Keeper to catalogue or arrange or even preserve the collection, or to give that aid to study required at the present time, without considerable additions to his staff of assistants. Among the more local collections, the East India Company has set a fine example by publishing two excellent volumes, prepared by their late venerable curator, Dr. Horsfield; in his task of preparing this catalogue he has been ably assisted by Mr. F. Moore, his under-curator. The Derby Museum of Liverpool will soon, we may hope, follow the same course; it is a most valuable one, and contains many unique specimens from our early expeditions. Its curator is quite adequate to the task. The Museum of the University of this city has, I am glad to say, been much improved, and a local collection is far advanced. I may remark that museums of this class should not, as is too often the case, attempt a general collection. The great object should be to obtain *typical specimens*, so as to explain the arrangements and the geographical distribution of animal life; afterwards a good British collection should be brought together; and, lastly, the local Fauna and Flora should be illustrated. Aberdeenshire, from its extensive seaboard and a country leading inward to a great elevation, is very rich in the variety of its productions; some of its ancient animals are already almost "forgotten," and what remain, from various causes, are rapidly decreasing in numbers, and are becoming gradually extirpated. Another object should be the illustration of any branch of industry or commerce for which the district is celebrated, and here there is a wide field in the Arctic fisheries. But the one great character of the present time is that of popular information—popular works on all subjects. This is, no doubt, all in the right direction, and shows the call for information; but it may be overdone. False information is worse than none. Some of our great principles cannot be studied against time, and diluted chapters from authors of reputation sometimes neither give the truth nor the author's meaning. These form a considerable staple in our weekly press. It is your duty then, who are presumed to know something of the various branches you profess, to inform and counsel and advise as far as you can the authors of those lesser works, when they will take advice, and to endeavour that at least accuracy is carried out in their endeavours to instruct others.

Upon the continent of Europe the progress of Zoology and Botany has been steady, and in our foreign possessions there is an advance. The melancholy events that have occurred in India and her unfortunate position have given a temporary shock there; yet the scientific journals of that country, which have brought so much to light, continue, and there is no country where we have been so much indebted to our military, engineering and medical officers for physical information. Their names would form a very long list. Col. Sykes, now attending this Meeting, deserves every praise; and among Scotchmen you have Elliot and Jerdan, M'Clelland and Adams,—the latter an Aberdeenshire man, and who has brought many new objects of interest to this country. In the younger countries we see advance more evident. Australia, Van Diemen's Land, and New Zealand, now that wealth permits leisure and luxury, have attended to science, and in most of the journals of those countries we have the papers of original observers, and by and by we shall have the results of the study of the remarkable productions of these lands made where the animals and plants live and grow. It is, however, in the New World where the greatest activity at present prevails. She has already with credit to herself sent out scientific expeditions of a general character, and those of Wilkes and Rae and Kane are well known, and huge works have sprung from each; the extent of territory now claimed by the American people has given rise to surveys and exploratory expeditions, and these are proceeding in all directions to fix the boundary lines, and the best railway routes to the Pacific,—naturalists and draftsmen, in fact all the necessary staff, accompanying each expedition, the results of which are published in reports to congress, in which they are assisted by the Smithsonian Institution of Washington,—a remarkable institution, supported by the munificent bequest of Mr. John Smithson, an Oxonian. The publications for this year have been the third part of Dr. Hervey's 'Nereis Boreali Americana,' and the large volume (1005 pages) 'On North American Ornithology,' by Messrs. Baird and Cassin. The reports are also devoted to general science, and will be found to possess great interest. The work of the greatest magnitude and importance to Natural Science in America, is 'Contributions to the Natural History of the United States,' by Agassiz, originally advertised to be completed in ten large volumes, but the subscription has so well filled up as to allow its extension even beyond the contemplated limits. Two volumes for the first year on the Testudinata or Tortoises, have been published, illustrated by thirty-four plates. An important part of these volumes is an introductory essay, which has been re-published in this country separately in an octavo volume. Louis Agassiz's 'Essay on Classification' embraces the whole range of the subject, which he treats in a wider and more comprehensive and less mechanical manner than has hitherto been done; but while I thus praise the work and the manner in which it is treated, and agree with a great many of the positions he has taken up, I must warn its readers that some subjects are treated of in a way Prof. Agassiz will not be able to maintain, and that to those who are unable or unwilling to think for themselves, the author's reputation will prove a guarantee not altogether to be trusted. It must be studied with great care and great caution; nevertheless I look upon it as the remarkable book of the year. There is another work upon a similar subject advertised, from which we may expect some curious reasonings, 'On the Origin of Species by means of Natural Selection,' by Charles Darwin.

Let me now say a word for Section D. At the first Meeting in York, in 1831, Zoologists and Botanists did not come forward in great numbers, and we had only five members, Daubeny, Greville, Henslow, Lindley, and Prichard. There was no Botanical paper, and only one on Zoology, 'On the Crystalline Lens of Vertebrata,' by Dr. now Sir David Brewster. In 1832 and 1833 the British Association met in Oxford and Cambridge—in 1834 at Edinburgh, where the attendance was greater than on any previous occasion, 1298 tickets being issued there—Dublin in 1835.

The proceedings of these first four meetings are extremely interesting, and a perusal of the volumes containing the Reports will show you how this now great body thought and acted in its early days; how it has crept on, and increased and matured its plans until it reached the high position in science which it now holds; and that I may not be said to think too highly of ourselves, or to state matters for which there is no foundation, the work of Section D. since the 27th of September, 1831, up to the conclusion of the Meeting for 1858, gives the following results:—There have been read, Reports, 95; Papers, Zoological, 411; Botanical, 213; or, in all, 719 Reports and Papers; and the amount of money granted to Section D. for scientific encouragement during the same period appears to have been about £1007. After the position that I have mentioned to you that the literature of our subject holds, I do not think that we can complain either of slowness or want of interest. Perhaps we have not been so popular as the members of Section C., but we shall not quarrel about which is the more important. I think we are mutually dependent on each other, and cannot well go on separately. Their science allows great scope for the imagination, and that may occasionally run riot. They have in charge the two great materials of which we all acknowledge the importance, and without the assistance of which we could not now be assembled here—coal and iron. We deal more in facts; but if ladies and gentlemen would only look around them, they would soon perceive that nearly all their necessaries and luxuries, whether of food or clothing, or for the adornment of their mansions or persons, depend chiefly on animal and vegetable products, and thus no one will dare to say that our Section is without interest; but the manner of viewing this rests upon ourselves, and if we will study these wonderful productions we see every day with minds impressed with the power and goodness of God in placing them around us, we shall find the investigation of them no weary work, but one full of interest and information. By these remarks I do not wish to claim for the British Association any undeserved influence; but it is now universally acknowledged that the example it has shown, and the various links it has joined between the different departments and the people cultivating them, have had a very decided influence on the promotion of science. At all the meetings of this Association which I have attended I have observed a great impulse given, both in the preparation for the meetings and after their conclusion; and if you will give it your attention, you will find that after we have left you, various matters will appear in other lights than those wherein you formerly viewed them. Various subjects will be suggested to you, and many of you will try to study and master this or that as your inclination leads, and my wish is that you may *persevere* and be *successful.*

BOTANY.

On some Uses to which the Nuts of the Vegetable Ivory Palm (Phytelephas macrocarpa) *is applied. By* GEORGE BENNETT, *M.D., F.L.S. &c., of Sydney, New South Wales.*

The Palm producing these nuts is found in South America about the river Magdelena, and is one of that class, throwing up large fronds from the roots, having no elevation of the trunk, and producing its large masses of fruit at the base of the enormous leaves. Some years since the nuts were only regarded as merely curiosities, and were also carved into fancy heads of dogs and other animals for the handles of parasols, umbrellas, and walking-sticks, for which purpose they still continue an article of commerce; but during a recent visit to Birmingham, I found that for the last two years these nuts have been used in that city in the manufacture of buttons; they are found durable and capable of receiving the various dyes equal to ivory, and are made at considerably less price than the latter material. This substance was first used for shirt buttons, but having been found to become discoloured, probably by the soap used in washing, fell into disuse until the dyeing them of various colours was adopted. The price of the nuts varies from twenty-two to thirty-two shillings per cwt., according to the quality and demand; and it is considered that from 400 to 500 tons are annually consumed in Birmingham, and gives employment to about 500 persons.

As regards the quantity of buttons manufactured, it of course varies; but one manufactory has been said to have made in one of their busy months as many as six thousand gross of all qualities and sizes; and the average quantity made in Birmingham per month may reach from eight to ten thousand gross. The buttons are used principally for gentlemen's jackets and vests, and also for ladies' mantles and children's dresses. The machinery employed is of different form from that used in the ordinary button manufacture, and enables the manufacturer to form the shapes cheaper and with more rapidity than by the ordinary lathe. [Specimens were exhibited showing the nut in the natural state when removed from the massive drupe in which it was contained, and in the various stages of manufacture; and also a series of buttons dyed of various colours, and arranged in the mixed varieties for commercial purposes.] The prices per gross vary, but they are sold at a cheap rate in comparison with similar articles made of other materials that are capable of receiving dyes of any durability. The refuse of the nuts is at present not used for any special purpose.

On the Failure of Bright Coloured Flowers in Forest Trees to produce Pictorial Effect on the Landscape, unless accompanied by abundance of Green Leaves. By GEORGE BUIST, *LL.D., F.R.S. Lond. & Edinb., F.G.S., Corr. Memb. Geog. Soc. Vienna, &c.*

In Northern Europe there is scarcely anything deserving the name of forest tree that affords flowers of sufficient brilliancy and size at any season of the year to affect the general colouring of the landscape; no tree or even bush of any magnitude puts forth its flowers until it is in leaf. The laburnum, lilac, roan tree, and hawthorn, are not deserving of the name of trees. The apple, the pear, and the gum tree, though in full flower before they are more than partially in leaf, are still in part tinted with green when their first flowers appear. The flowers of the chestnut, the horse-chestnut and the lime, beautiful as they are seen at a distance, approach so nearly to the general colour of the leaves, that the stranger to England, ignorant of their existence, could scarcely discover them half a mile away.

In India it is altogether different; with a brilliant display of flowers on some one variety of tree or other, of the very largest size, all the year round, many of the most gorgeous of them flower in winter, when the tree itself, and probably most of those around it, bear not one trace of green; and the result is, that the tree affording branches, which examined in the hand seem of unsurpassable beauty, are, when seen in the forest, rather an offence than a pleasure to the eye.

The *Bombax malabaricum*, the *Erythrina indica, Cochlospermum Gossypium, Butea* *frondosa*, &c., all flower when leafless; the flowers of all are beautiful in the hand; in the landscape they have no effect whatever.

The same cause that prevented me providing such a collection as I could have desired of illustrations of the geology of rocks around Suez, has precluded me providing anything like the supplies requisite to establish my position in the present notice; and I could have especially desired to have added to those prepared for another purpose, but which must do duty in this also; a series of the magnificent flowers which clothe our forests in summer when they are in their fullest glory of green.

The representations of individual flowers, as found in our scientific works, are sufficient to indicate their outline, general aspect, and botanical character; they fail altogether to convey any idea of their magnitude, and the magnificence of their appearance as seen in the forest. A bunch of flowers of the *Poinciana regia* seldom occupies less than a cubic foot; a single lotus flower has a diameter of seven inches; the snow-white transparent shaped flower of the *Datura alba* is seven inches from the calyx to the top of the petal, and four inches across. A single bunch of the flowers of the *Lagerstrœmia regina*, or of the *Acacia fistula*, will occupy a square foot of paper; and a sheet of elephant of six square feet in surface is about the smallest sized piece of paper on which a bunch of forest flowers should be drawn, if it be intended to give anything like an idea of them as they appear on the tree.

The examples now sent are:—

1. The *Butea frondosa*; 2. *Bombax malabaricum*; 3. the *Eriodendron anfractuosum*; 4. the *Cochlospermum Gossypium*—two of these being given both in flower and in fruit. They require no description; they indicate what is meant to be illustrated by them.

The two other drawings—the *Bignonia grandiflora* and *Bougainvillæa*—are the only illustrations of the converse position I have been able to prepare.

These require no description; the least effective, or rather the most distressing of them to the eye in the forest, are the *Butea frondosa* and *Bombax malabaricum*.

The drawing of the latter indeed in its seed-pods and wort, with only a couple of flowers, shows better pictorially, with its brown, black, green pods, than its bunches of crimson flowers.

The only illustrations of the converse I have been able to draw—we have them in the forest in hundreds of thousands—are the *Bougainvillæa* and the *Bignonia grandiflora*—both creeping plants, neither of them indigenous, plentiful in all our gardens, and in flower and leaf from December till May, a season at which our indigenous plants (which I meant to have drawn in addition) are either in flower only or in leaf only.

The two chance to cover the roof of my cottage for about thirty feet across and fifty along, and festoon and intertwine themselves amongst the trellis-work and in trees, producing chromatic effects of infinite beauty.

The *Bignonia* has a trumpet-shaped flower somewhat larger than that of the common honeysuckle, hanging in bunches nearly the size of the hand, and of thirty or forty flowers each; the bunches themselves being rarely more than from six to ten inches apart. The *Bougainvillæa* has small yellow insignificant-looking flowers, but they are enclosed in bracts of leaves, three in number, which from January till June are of the most beautiful amethystine purple, so gorgeous, indeed, as to conceal in a considerable measure the natural green leaves of the plant. The branches on which they grow are perfectly straight thorny twigs, from three to seven feet in length, with tendrils at intervals to attach them to any support in their neighbourhood. The two plants under review, beautiful when apart, are singularly so when combined. The contrast of the colours of the flowers, which might seem abrupt and harsh, is softened by the green of the leaves; this in the two being of a hue altogether different, I have never seen an artist who was not fascinated with the exhibition. My drawings are so imperfect in colour and so feeble, that I do not feel certain that in this case they will afford so much as an illustration of my meaning.

Illustrations of both my positions may be derived from dress. The most elegantly attired female, if arrayed in parti-coloured garments, looks spotty and ineffective as a portion of the landscape in a grove or avenue of trees; even in Hyde Park or

Kensington, the only effective dresses are the Royal Liveries and uniforms of the troops.

In India, again, nothing can be more effective, pictorially speaking, than a group of Parsee ladies, either in deep shadow of a grove, or in bright sunshine, with the simple dresses of China silk of uniform colour, or of not more than two and three, the most marked and emphatic, black, white, yellow, orange, or crimson, or two of them perhaps combined.

Note on some Peculiarities of the Silk Trees or Bombaceæ of Western India. By GEORGE BUIST, *LL.D., F.R.S.*

The Bombaceæ about to be noticed are,—1. The *Adansonia digitata*. 2. The *Bombax malabaricum*. 3. The *Bombax Pentandrum* of Roxburgh, or *Eriodendron anfractuosum*. 4. *Cochlospermum Gossypium*.

The *Adansonia digitata* is not a native of India. It is believed to have been introduced from Africa or from Korassan by the Portuguese some 300 years ago. In Malwa it is known by the name of "Korrasanee umlee," the Korrassan Tamarind —a decoction of the fruit tasting bitter and subacid like that of the pod of the wild tamarind. Graham describes it as prevailing chiefly on the sea-coast, its growth being promoted by the fishermen for the sake of its wood, which, on account of its lightness, makes excellent floats for their nets. It seems for half a century and more to have become as plentiful in the interior as on the shore. The ruins of the city of Mandoo near Indore, and of Bejapore in the southern Mahratta country, are surrounded or filled with it. Photographs of the tree from the latter locality will be found amongst the illustrations, showing, along with the drawings of Bombay trees, how sadly it is misrepresented in the best of our English botanical works. The largest of these trees I have met with measured 45 feet in girth; but we have them I believe twice as thick as this, flourishing in localities where they could not have existed for more than a century. The marvellous longevity ascribed to it from its size and the number of its rings seems without any foundation whatever. I have of late made portraits with measurements. I regret I have been so late in undertaking the task for every *Adansonia* of above 10 feet girth in Bombay, and a few years' observation will show the rate at which the trunk itself extends. The rapidity of its growth is surpassed by the extraordinary celerity of its decay; attacked by the grub of the larger Capricorn beetle, the *Lamia sentis*, the tree is eaten down in a few months. In 1842 a tree 45 feet girth was totally swept off by these hideous grubs from the face of the earth in six months. An account of the phenomenon was published at the time; a drawing of the tree will be found amongst the illustrations. I was in hopes of being able to send, for the inspection of the Association, the lower cut of a tree 18 feet in girth, which has been literally eaten across this spring, the top lying prostrate beside the trunk. I was unable to get it cut down in time, but hope it will make its appearance in England before the year is at at an end. The *Adansonia* begins to get into leaf in June; it flowers in July or August. The individual flowers are pure white, and of singular beauty, but of an odour so fœtid, that it requires some strength in the olfactories to get them drawn.

The *Bombax malabaricum* is a very large straight-stemmed tree, its bark and branches covered over with tremendous prickles. It is said to be a Brahman penance to climb up the tree; but the decree, like that which forgot to forbid the monk from boiling the peas he was ordered to have in his shoes on his pilgrimage, omits interdicting proper precautions now, and breeches and sleeves of leather may be made strong enough to defy or tear off the prickles. It flowers in February, and continues in flower till April. In the hand a branch in flower is gorgeous, in the forest no effect whatever is produced by it. The flowers, which when spread out present a circular surface of 2 inches in diameter, have the faculty of secreting a large amount of sweetish moisture; the birds, especially the crows, drink with avidity. That this is not dew, but a secretion from the plant, I ascertained by enclosing a number of flowers in wide-mouthed bottles, and making all tight with wet membrane, so as to cut off all communication with the air, without injuring the petals, or interfering with circulation or respiration. On an average they afforded about fifty grains weight a day from each flower. The same thing goes on for several days in the case of branches kept in a room; and I often had a drawing destroyed by the accidental spilling of half a tea spoonfull of mucilaginous water on the paper. The seed-pod when ripe is black; and I trust those now forwarded will reach in sufficient safety to manifest the manner in which the seed with its silky covering is packed up and afterwards dispersed. Each seed is about the size of a small garden pea. It is, when in the pod, enveloped in a little cube of silk about half an inch each way, slightly yellowish in the exterior. Liberated by the bursting of the pod, when dry it flies out into the most beautiful smoke-like spirals and whorls that can be imagined. Some few flowers generally remain on the tree till the bulk of the seed-pods are ripe. The extraordinary beauty of the various portions of the seed-pod of the *Cochlospermum Gossypium* (of which two varieties are sent) will be seen from the specimens accompanying.

Note on the Aversion of certain Trees and Plants to the Neighbourhood of each other. By GEORGE BUIST, *LL.D., F.R.S.*

The accompanying drawings will afford some striking illustrations of the aversion of certain plants to the vicinage of each other, not on the score of want of light, but on that of want of air. I do not know that there is anything peculiar to our Indian vegetation in this beyond what might be looked for from the heat of the sun and the rapidity and luxuriance of the vegetation. The first example is that of two Casuarina trees eight years old, 40 feet in height, and 32 inches in girth, growing to the right and left of the portico of my house. The house itself stands nearly north and south; the portico and much of the roof is covered with creeping plants. The Casuarinas on each side bend away from this in nearly equal curves, one inclining to the north, and the other to the south, receding 2 feet 8 inches at the height of 12 feet, so long as they are opposite to the other plants; when above the roof of the portico, they regain their perpendicularity immediately.

The other case is that of young teak and a date palm, of no great size, and their aversion to each other's neighbourhood is still more conspicuous. I have taken offsets with a plumb and rule from each so as to give the precise amount of their retirement.

A Diatomaceous Deposit found in the Island of Lewis. By H. CAUNTER.

The deposit contained several species of Diatomaceæ, and is situated in a lake-district 150 feet above the level of the sea, and had evidently been deposited from a lake now dry. It is situate in the western part of Uig, about five miles from the parish church.

An Account of the more remarkable Plants found in Braemar. By MR. CROALL.

Notes on the Upper Limits of Cultivation in Aberdeenshire. By Professor DICKIE, *M.D.*

In a previous communication it has been shown that the three upper zones of vegetation in Britain are well-represented in Aberdeenshire. Adopting as our standard Mr. Watson's characteristics ('Cybele Britannica,' &c.) of the Agrarian Region in Britain, we find that since certain species of indigenous plants, whose presence marks the Infr-agrarian and Mid-agrarian Zones, are absent from Aberdeenshire, as well as from the two neighbouring counties, and, I believe, from Scotland, the Supr-agrarian is the only one of the three which can apply to this district.

The upper limit of *Pteris aquilina* (the common Brake Fern) is considered also as marking the upper limit of the supr-agrarian zone, and therefore also that of cultivation in Britain. The limit of this Fern in Aberdeenshire varies from 1600 to 1900 feet; very rarely, however, does it attain the latter. In some localities, on the bare stony sides of hills, I have found the limit to be 1600 to 1700 feet: even in places where there is no cultivation, the common Mole makes its tunnels at about the same height. On Morven I have seen it at 1723 feet; and near Ballater, at Brakely, it reaches 1642; at the Pulock Moss, 1735; and on the Khoil, 1800 feet.

At various places, even more than forty miles from the sea-board, cultivation at high altitudes is frequent; farms at an elevation of one thousand feet are numerous, and some are far higher. The heights of the following places, where oats, barley, &c. are or have been grown, were ascertained by means of the mountain sympiesometer and aneroid: Near Ballater—the Line 1108, Corrybeg 1126, Lin Mui 1300, Easter Morven 1400; Braemar—Castleton 1160, Tomantoul 1500, Glen Lui, &c. 1600; Gairn-side—Glen Fenzie 1500; Strathdon—Brasacheil 1383 feet. The river Don at the Bridge of Corgarf is 1280 above the sea; and at places near it, cultivation extends much higher.

At the farm of Lin Mui above-mentioned, there are several old Ash trees: the two largest of these in 1843 I found to be, at the base, respectively five feet and four feet six inches in girth; at present (September 1859) their girths are five feet six and five feet four inches: their rate of growth at such elevation is therefore slow. At Altguisach, near Loch Muick, above 1400 feet above the sea, and fifty miles inland, most of the ordinary culinary plants are grown, also the smaller fruits, as red, white, and black currants, &c.; Bay and Portugal Laurels, standard Roses, &c., also succeed. There are likewise thriving Larch trees, the girths of four of the largest of which were recorded in 1843 (Dr. Dickie on Forest and other trees of Aberdeenshire, 'Scottish Agricultural Journal'). In that year they had each respectively a circumference, near the ground, equal to four feet nine, four feet five, four feet, and three feet six inches; these trees are now (September 1859) equal to five feet seven, five feet six, five feet four, and five feet: they have therefore grown more rapidly, in proportion, than the Ash trees already alluded to. The garden of Achernach in Strathdon is at least 1250 feet above the level of the sea, and about fifty miles inland; opposite it is the Greenhill, not less than 1500 feet in height, which in the earlier months of the year prevents the free access of the sun's rays. The produce of this garden is reported as considerably later in arriving at maturity than at some places in the vicinity: at these last, the season of the smaller fruits is over before they are ripe at Achernach.

A few records have been consulted with the view of ascertaining the average period necessary for the maturing of oats at different elevations, and at various distances from the sea: though not sufficiently numerous to afford satisfactory conclusions, it may be interesting for the present to state them. At elevations not exceeding five hundred feet above the sea, and about twenty miles from the coast, the mean time is one hundred and seventy-two days; at places exceeding one thousand feet, and from forty to fifty-five miles inland, the result is one hundred and seventy-nine days.

Remarks on the Flora of Aberdeenshire. By Dr. Dickie, *Professor of Natural History, Queen's College, Belfast.*

A summary of the physical characters of the county may be first given. A line from Peterculter on the borders of Kincardine to Pennan on the borders of Banffshire, separates two portions which present very different physical aspects; the part to the east of this line presents no elevation exceeding 900 feet; to the west there is a general and increasing elevation of the surface. This becomes obvious if we trace the levels of the two principal rivers, the Dee and Don; the former has an elevation of 1640 feet, at a distance of seventy miles—in a straight line—from its termination; the Don, fifty-five miles inland, is 1240 feet above the sea. Again, if we take a general view of the heights of mountains in sections of ten miles from east to west, we observe a regular increase in height, till we reach a zone in which none of the numerous mountains are lower than 2000 or 3000 feet; and many exceed 4000,—the extreme elevation being that of Ben Muich Dhui, viz. about 4320 feet, and therefore in Britain second only to Ben Nevis.

Omitting here other details respecting the shore-line, prevailing rocks and soil, temperature, rain, &c., the following is a summary of conclusions respecting the vegetation.

Excluding upwards of forty species, many of which, though now extensively diffused, have doubtless been introduced at a comparatively recent period, the indigenous flowering plants amount to 635, consisting of 458 Dicotyledons, and 177 Monocotyledons: these are distributed among 53 natural orders of the former, and 11 of the latter. The flora, therefore, is not rich as regards mere numbers, nevertheless it comprehends many species of great interest. Adopting the following views of Mr. Watson as to type of distribution in Britain, we are better prepared to understand the peculiarities of the Aberdeenshire flora. The British type comprehends those of almost general occurrence in England and Scotland; the English, those general in England and rare in Scotland, or absent from the northern districts; the Scottish, those which are rather general in the lower districts of Scotland, some being found also in the north of England, but disappearing southwards; the Germanic, those confined mainly to the south-east of England; the Atlantic comprehends species found principally in the west, and rare or wanting in the east; the Highland type comprehends those which characterize the mountains of Wales, those of the north of England and of Scotland—some, however, descend to the sea-shore in the north and west of Scotland; in the Local type are included a few species so partial in occurrence as not to come under any of the other types.

The flora of Aberdeenshire includes only nine of the English, two of the Germanic, and of the Atlantic type only one; plants of these types, form, therefore, a very small proportion of the entire number, and are for the most part very local. Of the British type there are 485 species, consisting of 353 Dicotyledons, and 132 Monocotyledons; those of the Scottish type are 47 in number, comprehending more than one-half of the British species referred to that type—some of these, as *Linnæa, Goodyera, Trientalis*, &c., are very plentiful near Aberdeen and in the lower district generally. Those of the Highland type are estimated at 100 in the whole British Flora; of these, eighty-nine species are found in Aberdeenshire, some of which are confined to the inland districts, a few others descend even to the sea-level. In the interior, at different altitudes, we meet with such plants as *Thalictrum alpinum, Nuphar pumila, Aratris petræa, Cerastium alpinum, Astragalus alpinus, Mulgedium alpinum, Arbutus alpina, Veronica alpina*, and various interesting species of *Saxifraga, Hieracium, Salix, Juncus, Carex*, and *Poa*.

In addition, therefore, to many of the species which are widely diffused in Britain, Aberdeenshire is characterized by a general intermixture of those belonging to the Scottish and Highland types.

The physical characters of the country, already indicated, are such that it presents an excellent field for studying the distribution of the species in zones of altitude. In many of the lower districts the British and Scottish types occur in fair proportion, with occasionally a few of the Highland type; as we pass to the interior, many of the British and Scottish become rare, and finally disappear; about the highest points the species are few, and belong solely to the Highland, the flora becoming entirely Arctic in character. Thus only seven species, all of that type, are found on the extreme summit of Ben Muich Dhui, in the proportion of four Monocotyledons to three Dicotyledons.

The three zones of the Arctic Region in Britain, as defined by Mr. Watson in his 'Cybele Britannica,' are on the whole well defined in Aberdeenshire, viz. the infr-, mid-, and supr-arctic. In the first of these, embracing an elevation of 1600 to 2100 feet, the flora presents a mixture of British, Scottish, and Highland species; in the second or mid-arctic, from 2100 to 3000 feet, the British and Scottish types are rarer, and the more interesting species of the Highland prevail; in the supr-arctic, from 3000 to 4320 feet, Highland species are most general, and at the extreme points, as already stated, they alone are found, and only a few species,—the flora at such extreme elevations being, therefore, far more meagre than even in the highest latitude of the Arctic zone known to us, Dr. Kane having found more than twenty flowering plants in latitude 81° N.

On the Temperature of the Flowers and Leaves of Plants.
By E. J. Lowe, *F.L.S.*

During the spring and summer of the present year, I have made some hundreds of thermometric observations in order to ascertain the temperature of plants and flowers in comparison with that of the air and of grass. For several months, grass was always colder than flowers; but when hot summer weather set in, the reverse took place frequently. An extract from this series will show the state of the temperature at different times:—

February 26th. Greatest heat on grass 50°·0, on *Crocus vernus* 54°·0, and on *Crocus aureus* 54°·5.

March 28th. Greatest heat on grass 61°·5, on *Narcissus pseudo-narcissus* 63°·7.

April 1st. Greatest cold on grass 10°·0, on *Narcissus pseudo-narcissus* 10°·5.
April 7th. Greatest heat on grass 82°·5, on *Saxifraga biflora* 84°·7.
April 8th. Greatest heat on grass 40°·9, on *Bellis perennis* 41°·8.
April 9th. Greatest heat on grass 65°·2, on *Bellis perennis* 66°·7.
April 17th. Greatest heat on grass 68°·7, on leaves of *Bellis perennis* 71°·0.
April 21st. Greatest heat on grass 64°·8, on *Saxifraga biflora* 73°·8, and on *Alyssum tortuosum* 67°·3.
April 22nd. Greatest cold on grass 21°·6, on leaves of *Valeriana tuberosa* 23°·0.
Greatest heat on grass 50°·2, on leaves of *Valeriana tuberosa* 53°·8, on *Alyssum tortuosum* 54°·5, on *Daphne cneorum* 57°·5, and on *Iberis sempervirens* 61°·0.
April 23rd. Greatest heat on grass 57°·5, one foot above grass 54°·3, two feet above grass 52°·5, on *Daphne cneorum* 69°·7, on *Gentiana acaulis* 73°·8, on *Veronica alpina* 68°·1, on *Iberis sempervirens* 66°·0.
May 2nd. Greatest heat on grass 60°·5, on *Iberis sempervirens* 63°·2, and on *Alyssum tortuosum* 64°·2.
May 3rd. Greatest heat on grass in shade 58°·4, on *Alyssum tortuosum* 65°·6.
May 5th. Greatest heat on grass 63°·0, on leaves of *Sedum acre* 66°·1, on leaves of *Dianthus deltoides* 61°·9, on *Alyssum tortuosum* 68°·0, on *Iberis sempervirens* 75°·5, on *Gentiana acaulis* 76°·8.
May 6th. Greatest cold on grass 28°·9, on leaves of *Lilium Martagon* 28°·7, and on leaves of *Hyacinthus orientalis* 31°·2.
Greatest heat on grass 69°·2, on *Gentiana acaulis* 73°·8, on *Anemone Hortensis* 79°·0.
May 7th. Greatest cold on grass 32°·0, on leaf of *Brassica oleracea* 33°·8, on leaves of *Althæa rosea* 33°·6, and on leaves of *Thymus vulgaris* 35°·2.
Greatest heat on grass 68°·4, on *Anemone hortensis* 74°·0, and on *Gentiana acaulis* 74°·3.
May 8th. At 2h 45m p.m. temperature on grass 70°·0, on *Hyacinthus albus* 74°·1, and on *Bellis hortensis* 74°·4.
Greatest heat during the day on grass 85°·0, on *Bellis hortensis* 87°·0, on *Phlox procumbens* 88°·7, and on *Hyacinthus albus* 82°·9.

The above examples will be sufficient to show that the readings of thermometers placed close above flowers are almost always higher than of those placed above grass.

The mean of thirty-nine readings on *Gentiana acaulis* shows this flower to be 2° warmer than that of grass, the greatest difference being 7°·9. Other observations show *Daphne cneorum* to be 1°·2 warmer than grass, the greatest difference being 3°·7; *Iberis sempervirens* 2°·3 warmer; *Alyssum tortuosum* 2°·3 warmer; *Saxifraga biflora* 3°·0 warmer; *Red daisy* 1°·7 warmer; *White daisy* 0°·2 warmer; *Veronica alpina* 1°·9 warmer; and *Alyssum tortuosum* 2°·4 warmer than the leaves of *Reseda*, and 2°·3 warmer than the leaves of the hollyhock. The greatest difference has occurred with a yellow tulip: it was never less than 10° warmer than grass, and on May 15th was 12°·5 warmer.

The observations have been made with a delicate set of instruments furnished expressly for the purpose by Messrs. Negretti and Zambra, and the flowers have been experimented upon both from the growing plant and from cut flowers placed in bottles of water. The above observations have all been taken in sunshine; however, from experiments made in the shade, it is found that the difference becomes much less.

Remarks on the Cultivation of the Opium Poppy of China. By Dr. M'Gowan.

Remarks on Vegetable Morphology and the Theory of the Metamorphosis of Plants. By Maxwell T. Masters.

In this paper the morphological views held by the Greek botanical writers were briefly passed in review; and especial attention was called to a quotation from Nicholas of Damascus, which seems to show that the foliar nature of the fruit was not unsuspected by Aristotle and the other writers to whom Nicholas was chiefly indebted for his opinions; moreover such an origin of the fruit was assumed on physiological grounds that are strikingly in accordance with modern views. In the middle ages botany shared the fate of most other branches of learning; but towards the end of the 13th century, Albertus Magnus, a Dominican friar, wrote sundry treatises on botanical as well as on other subjects, which prove him to have possessed ideas much in advance of his age. He directed attention to the relationship existing between the simplicity of vegetable life and functions, and the nearly homologous nature of the external and internal parts of plants.

The systematic writers of the 16th and 17th centuries did not pay much attention to the theoretical construction of the flower, although they recognized the foliar nature of the calyx and corolla. Joachim Jung, professor at Hamburg, who died in 1657, seems to have understood the true nature of several parts of the plant, such as the root and stem, compound flowers, &c. A century later, Wolf published his 'Theoria Generationis,'—an essay remarkable for the account of the development of the flower and its parts. The order of successive appearance in the different whorls of the flower, as given by Wolf, is not in accordance with more recent investigations; nor is his hypothesis, that the stamens are to be considered as buds axillary to the petals, consonant with their true position with reference to the petals. This notion, somewhat modified, however, has met with supporters in recent times, in the persons of Agardh and Endlicher. Neither Linnæus nor Goethe have expressed themselves so clearly on the subject of the metamorphosis of plants as Wolf has done, who, after referring all the parts of the flower to the leaf type, says, "in a word, we see nothing in the whole plant, whose parts at first sight differ so remarkably from each other, but leaves and stem, to which latter the root is referable." The proper mode of investigating the morphological nature of the organs of plants is pointed out, and the formation of the flower is, in pursuance of this method, referred to a gradual diminution in the powers of vegetation.

The chief points in the more widely known 'Prolepsis Plantarum' of Linnæus, were then alluded to, to show that Linnæus, from original research in natural as well as in abnormal formations, had arrived at the same result as Wolf had done from the study of progressive development.

Linnæus's inductions were marred by hypothetical assumptions as to the bud-like nature of the petals, stamens, &c., the relationship between the whorls of the flower and the layers of the stem, and the fanciful theory of anticipation. Linnæus's remarks on the nature of buds, supported by a comparison with *Volvox globator*, is, however, quite consistent with the modern doctrine of metagenesis.

The essays of Wolf and Linnæus were published so nearly at the same time, that it is hardly possible to assign the priority to either in enunciating the foliar nature of all the floral whorls, and of thus originating the modern doctrine of metamorphosis. Wolf's first essay preceded that of Linnæus; his second essay, though published six years subsequently to that of Linnæus, is a revision of the first; and in it is contained by far the clearest account of the morphology of the flower,—an account deduced from the investigation not only of facts similar to those which led Linnæus to his conclusions, but also of the development of the flower—a line of research which he had originated, and the results of which he had published before the appearance of the 'Prolepsis.' For these reasons the author considered the chief merit to be due to Wolf.

Goethe's 'Essay on the Metamorphosis' was published thirty years after the essays of Wolf and Linnæus just referred to; and although on many points Goethe was anticipated by previous writers, there can be little doubt that with Goethe the idea was an original one; that from Linnæus he gained, *directly*, little, from Wolf nothing. Had it not been for Goethe's memoir, neither the essays of Wolf nor of Linnæus would have sufficed to establish the theory on so firm a basis as that on which it now rests. Goethe considered the so-called nectaries as intermediate stages between the petals and the stamens, explaining in this way the *corona* of *Narcissus*, *Passiflora*, &c. This view is opposed to that of Schleiden. The author of this paper adduced several circumstances based upon actual observation and upon analogy, in support of the opinion held by Goethe. It is well known that DeCandolle's classification of fruits was based on Goethe's explanation of the true nature of this organ—wherein, however, the poet-philosopher was completely forestalled by

Wolf, and to a less extent by Linnæus. Instances were cited to show that Goethe, by reason of what he wrote on the nature of buds, their homologies with seeds, the phenomena of vegetative reproduction and growth, the successive production of node after node, the doctrine of alternate expansion and contraction, &c., may fairly be considered as the pioneer of the doctrine of the rejuvenescence of plants, of the theory of the vibrations of the metamorphosis, and, to a less extent, of that of metagenesis.

The paper concluded with some remarks on the axis as playing an essential part in the metamorphosis, and on the difficulty in some few cases of distinguishing with absolute certainty between axis and stem,—the author believing that in these cases mere expediency led writers to refer certain organs to the leaf or to the axis respectively, and to make the assertion that there are no intermediate stages between stem and leaf. Rather may we not consider leaf and axis as parts of one and the same organ—that in most cases both parts are developed and take part in the metamorphosis, while in other cases the one predominates over the other? Is not this view consistent with the absolute identity of original structure and with what we know of cellular growth in the vegetative organs of plants? Do not all these instances of Nature's pliability, as manifested in the metamorphosis, afford a warning against those systematists, who, relying upon some slight or inconstant variation in some one or more organs, found thereupon an unstable, unphilosophical assemblage of genera and species?

On the Colours of Leaves and Petals. By W. E. C. Nourse, *F.R.C.S., Fellow of the Royal Medical and Chirurgical Society.*

From the facts enumerated by the author, it appears that,

1st. Variegation of leaves is of two kinds,—that in which the green patch is central, having light-coloured edges; and that in which the centre is yellowish, with green edges.

2nd. Variegation is not the result of etiolation, nor yet of any defect or imperfection of tissue.

3rd. It is intimately connected with the vital process of nutrition, both in the plant generally, and in the tissue locally, in some peculiarity of which it seems to consist. That peculiarity, though not a defect, is not connected with exuberance of nutrition.

4th. In variegated leaves the deepest colours are found in contact with the veins, which is the situation where the growth of the leaf proceeds most rapidly.

5th. Light is thus excluded, and the process of growth and nutrition indicated, as the cause of variegation in leaves.

6th. The first appearance, both of the extra tints of leaves, and of their autumnal tints, whose seat is always in the rete, is invariably either about the capillaries of the upper set of veins, or about the main trunks of the under ones. These two points are therefore evidently the seat of some speciality of function, over which light has a marked influence.

7th. Leaf-colours thus originate from two different agencies. There are the colours produced in contiguity with the veins, and mainly within the influence of the sap; and there are the colours produced beyond the full influence of the sap, and chiefly under the control of solar light. Besides these, there is a third set of tints produced by the circulation of a coloured sap, as in beet root, red cabbage, &c.

8th. White flowers have nothing to do with etiolation or imperfection of tissue, but contain in their cells a white matter perfect after its kind, and attain their fullest development under the full blaze of solar light.

9th. Brilliant colours are often seen in the rudimentary petals still enclosed in the bud, so that no light could reach them. Such colours are usually in contact with the veins, showing their connexion with the process of nutrition.

10th. The process of nutrition is one of the most important vital powers the plant possesses, since without it the very identity and existence of the individual must cease. With respect to colour, this power exhibits its effects *occasionally* in the production of tints quite independently of light, and *constantly* by the formation of tissues not calculated to take on this or that colour at random, but each specifically adapted to elaborate, under the appropriate stimulus of light, its own proper tint or succession of tints, and no other.

11th. The subordinate but important office of light is to influence the development of whatever colour the tissues are prepared for, which it effects in two ways. As to degree, according to the presence, diminution, or absence of light, the colour may be either brilliantly or feebly developed, or totally absent. As to change of colour, light facilitates, heightens, or even wholly brings on, whatever modifications each particular portion of plant-tissue is prepared for, whether in growth, maturity, or decay; but it cannot originate changes to which there is no inherent tendency.

On the Vegetative Axis of Ferns. *By* GEORGE OGILVIE, *M.D.*

This communication embraced two principal points—the general form of the rhizome of ferns, and its internal structure. The stems of our British species at least may be reduced to three forms—the creeping rhizome, and the caudex, simple or branched. These differences depend on the proportionate development of the vegetative axis itself and the two kinds of appendages with which it is furnished, the black wiry rootlets, and the persistent bases of the leaf-stalks. In the general arrangement of the vegetable organization there is a distinct local separation between the leaves and the rootlets, the latter being confined to the lower or underground extremity of the stem. Yet this is not always the case even in arborescent forms; for in some species (as of *Ficus*) they arise also from the leaf-bearing portions of the trunk. Further, in all classes of plants we meet with what are termed rhizomes, *i. e.* prostrate or underground stems, from the whole extent of which leaves and rootlets are emitted side by side: the stems of all our indigenous ferns are of this kind.

In the variety above referred to as the creeping rhizome, the stem is much drawn out, so as to form a cord which branches frequently in its course along or just under the surface of the ground, and emits at intervals fronds from its upper, and rootlets from its lower aspect. In the common Polypody the petioles break off from the stem, leaving scar-like marks at the points of articulation; but in the other species and in the Braken, the lower extremities of the leaf-stalks remain adherent after the upper portions and the fronds have decayed away, and by their comparative state of preservation mark the limits of the growth of the rhizome in successive years.

In the form of the stem termed a caudex, the axis is less drawn out, and more closely set with rootlets and petioles, and the latter are arranged in a spiral manner. In the genus *Asplenium*, in *Osmunda regalis*, *Blechnum boreale*, *Allosurus crispus*, *Lastrea Oreopteris*, and perhaps some other species, the caudex branches in a dichotomous manner by the repeated duplication of the terminal bud, and the so-called root acquires a shrubby character when the axis is exposed by the removal of the rootlets and petioles.

In some ferns, however, the caudex never branches at its extremity; and when offshoots occur, they arise from lateral buds. This is the case in the massive imbricated root-stock of the Male Fern and some other species of *Aspidium*. This form presents many points of resemblance to the stem of a Tree-fern, though its small development and horizontal line of growth prevent its forming any conspicuous trunk above the surface of the ground. The resemblance becomes more apparent when the persistent bases of the decayed fronds are cut off, and only the central axis left, marked with spiral rows of cicatrices like the scars which occur on the stem of the Tree-fern.

The chief peculiarity of the *internal* structure is the reduction of the fibro-vascular system to a netted cylinder, imbedded in the general cellular tissue of the stem, and giving off fasciculi both to the petioles and the rootlets. The annual increments of the stem—which in Exogens form a series of conical envelopes of continually increasing dimensions, each entirely enwrapping its predecessors, and which in Endogens have been compared to a series of envelopes of similar form, but of *uniform* size, piled up into a column by successive superposition—are in the fern-stem represented simply by annular additions to the upper extremity of the netted cylinder. The fibro-vascular bundles of the petioles, immediately on entering the stem, branch out to form an upward extension of this cylinder in the growing extremity of the corm; but they have no downward prolongation, the isolated fasciculi of the interior of the endogenous stem and the successive annual woody layers of the exogen being alike wanting. A fern-stem cut across exhibits simply an expanse of cellular tissue divided into a medullary and a cortical region by the netted cylinder, whose transverse section presents the appearance of an interrupted circle of fibro-vascular tissue. The interspaces appear to have a certain analogy with the medullary rays of the exogenous stem. When the network is dissected out, its anastomosing cords are seen to be connected with bundles proceeding to the rootlets, as well as with the fibro-vascular fasciculi of the petioles.

The rootlets may be shown to be of independent origin, and not mere downward prolongations from the leaf-stalks; and there are strong reasons for believing this to hold good also in the higher orders of plants, though theoretical views of a contrary import have prevailed to some extent.

The arrangement of the vascular system as now described, is very regular in all the species; but there is great diversity in the course of the dark-coloured or woody tissue, which will require further investigation.

The paper was illustrated by diagrams, and by preparations and dissections of our indigenous ferns, with some comparative specimens of the arborescent species.

On the Structure and Mode of Formation of Starch-granules, according to the principles of Molecular Science. By GEORGE RAINEY, *M.R.C.S., Lecturer on Microscopical Anatomy at St. Thomas's Hospital**.

Notes on the Arctic Flora.
By JAMES TAYLOR, *Student of Medicine, Aberdeen.*

The following remarks are founded on two voyages to the shores of Davis's Straits. From 72° to 74° N. on the east or Greenland side, the coast is rocky and precipitous; along this side also there are numerous islands, more or less conical in form, which also present precipitous cliffs. The land in the interior consists of a complicated system of ravines and mountain ranges, the former usually occupied by glaciers; between 74° N. and Cape York, the surface seems to present an extensive "Mer de Glace." The soil varies in its nature, is frequently of small depth, and often has more or less peat on the surface.

The land on the west or American side of the strait presents an extensive plain along the seaboard, the mountains in the interior being fewer than on the east side, but apparently higher; this land is also destitute of glaciers, and its sea free from icebergs; any which occur have been drifted from some other quarter. In the interior there are mountains, plains, and numerous lakes.

The east side is sooner clear of snow than the west side, just as that border of the strait is soonest clear of ice; on the land the snow first disappears in a zone 50 to 100 feet above the sea, extending thence upward and downward.

The Flora is on the whole rich and varied; about 116 species of plants were collected (a list was given), belonging to 24 natural orders, in the proportion of 27 Dicotyledons to 38 Monocotyledons; and in addition, 3 Ferns, two species of Lycopodium, and one of Equisetum, besides numerous mosses and lichens. *Saxifraga oppositifolia* and *Salix herbacea* were the first seen in flower, the former in March, the latter about the end of May; the species of ranunculus and *Papaver nudicaule* are among the latest; *Saxifraga Hirculus* is also late, flowering the middle of August. *Ranunculus sulphureus* and *Papaver nudicaule* burst through a covering of snow at the time of flowering. On many species the mature fruit is perfectly preserved under the snow during the long winter, and thus different birds find abundance of food in spring; the natives also avail themselves of the same supply. The buds on the peduncle of *Polygonum viviparum* are greedily devoured by the ptarmigan and snowflake.

On the Growth of Trees in Continental and Insular Climates.
By DANIEL VAUGHAN.

A study of the peculiar characters which certain meteoric influences impart to vege-

* See 'Journal of Microscopical Science,' vol. viii.

tation in different regions, must assist very materially in removing the veil which now enshrouds the mysterious operations of vegetable life. While the sterility of deserts is to be ascribed, in most cases, to the want of rain, the long droughts to which many extensive plains of the Old and New World are occasionally subjected may be regarded as very unfavourable to arborescent vegetation. It has been long believed that the western prairies of this continent were brought into their present condition by the labour of former inhabitants, who exterminated the forest, and, in after ages by means of fires, prevented it from regaining possession of the land; but many facts show that the absence of trees in these localities corresponds to the result which unassisted nature may be expected to produce. Since my conclusions on this subject were first made known, I have learned that some of them are not new; but my present object is to show that the facts which observation reveals admit of an important generalization, and that these vast plains only exhibit the effects of causes which operate on a greater or less scale in many other parts of the earth.

As a general rule, mountainous districts and places near the sea are most favoured with frequent supplies of rain; but the case is different in great plains, especially in those occupying the interior of continents. In some, as in those of the Mississippi Valley, no deficiency is exhibited in the actual amount of rain which falls annually; but it generally comes in a small number of excessive showers, often separated by very long intervals of dry weather. During these dry periods the elaboration of the sap in trees is carried on in a very imperfect manner; and the woody tissue formed under such unfavourable circumstances must be devoid of proper strength and durability. The tendency to decay which it soon manifests, must be gradually communicated to the whole vegetable structure, and thus a dry season inflicts a very serious and permanent damage on the forest; but though it may exterminate the herbaceous plants, the loss will be speedily repaired by the copious rains of the succeeding year.

The effects of these circumstances on vegetation may be traced in many regions. Trees of the same kind attain the greatest age and afford the most durable timber, in places where rains are supplied in the greatest frequency,—as on islands, on the sea-coasts of continents, or on mountainous districts. The most numerous and the most extraordinary cases of arborescent longevity, are to be found in the islands of Sicily and Teneriffe, in the mountains near the Syrian coast, in the mountainous territory of California, in the forests of Guiana, and in the British Isles. It is different on plains, especially in those places which are remote from the sea. The forests of European Russia, though very extensive, rarely furnish very durable timber; and the Russian ships are characterized for their great liability to decay. It is also well known that the timber of the Mississippi Valley is far less durable than that of the states bordering on the Atlantic; and the increasing number of hollow trees which we meet on retiring from the sea-coast, may be regarded as indicative of the feeble health and the declining condition of the western forests.

It could not be expected that even the more gigantic vegetable forms could long withstand influences so detrimental to their health and vitality. Accordingly in extensive continental plains, the forest, by a constant degeneracy of its members, must be often rendered incapable of spreading its dominion, or of contending successfully with the grass for the possession of the soil. The fertility of these plains, by promoting a more rapid growth of the wood, increases its tendency to decay; and accordingly trees are generally absent from the more fertile parts of the prairies, while they are to be found in localities where the land is too poor to give an undue luxuriance to vegetation. They are also found growing vigorously along the banks of rivers, where the soil has the greatest fertility; but here the watery vapour which constantly rises into the air diffuses copious dews around, and compensates, to some extent, for the deficiency of rains.

That the evaporation of the water which falls on the leaves of plants is concerned in promoting their vegetative functions, has been noticed by Boussingault; but many facts show that its influence is chiefly felt in the formation of woody fibre. The lignifying process, however, depends as much on the extent of the foliage as on the frequency of rains; and according to Loudon, the pruning of forest trees has been always found very detrimental to the durability of their wood. But experience has long shown the necessity of pruning fruit trees; and it appears that as the ligneous formation is checked, the extractive matter of the sap is rendered more capable of affording nutriment to fruit. It is not, however, beneficial to prune much in continental climates, where dry seasons diminish the tendency to form wood; and, indeed, the vineyards and orchards west of the Alleghany Mountains have suffered much from being subjected to the modes of culture which have been adopted with much success in the moist countries of Southern and Western Europe. During the dry summer of 1854, it was observed in Ohio that those grape-vines which were not pruned, produced the most abundant crops; and other facts might be adduced to show that a diminution of foliage and a deficiency of rains operate, in the same manner, in checking the ligneous formation and promoting the development of fruit.

To account satisfactorily for these results, and to remove the difficulty hitherto found in reconciling the effects of pruning with the theory of vegetation, it will be necessary to regard the soil as furnishing, not only the mineral ingredients, but also much of the organic matter required for vegetable nutrition. Though there is abundant evidence that carbonic acid is decomposed by plants, it cannot be regarded as the exclusive source of their carbon; and the explanation which the advocates of the carbonic acid theory give for the production of wood in the trunk of a tree by a chemical decomposition which is entirely confined to the leaves, seems to be unsatisfactory. We cannot ascribe the source of vital energy in plants to the mere act of decomposing carbonic acid; for it is evident that the forces associated with vitality must experience a loss, instead of a gain, in overcoming the resistance of a powerful chemical affinity. While vegetative power is mainly derived from the heat and light of the sun, it appears to depend in a great measure on the evaporation from the leaves and the chemical action going on in the soil. Such operations might be expected to create a circulation of galvanic currents along growing plants; and though experiments show that these currents must be extremely feeble, they may be rendered very efficient for controling chemical affinity, by the agency of cells, ducts, membranes, and other appendages of vegetable life.

Mr. J. Yates exhibited the cones and leaves of several species of Cycadaceous plants grown in England. He stated that the Cycad known as *Dioon edule* was the *Macrozamia pectinata* of Leibmann. He gave some account of the method of culture of these plants, and stated, they required an average temperature of 70° Fahrenheit.

Zoology.

On the Birds of Banchory. By Dr. Adams.

On a New Zoophyte, and two Species of Echinodermata *new to Britain. By* Joshua Alder.

The species described were dredged by George Barlee, Esq., off the Shetland Islands, in the summer of 1858. The zoophyte was a peculiar form of the genus *Campanularia*, distinguished by having an operculum of a roof-like form, sloping on each side from two opposite angles. Mr. Alder named it *Campanularia fastigiata*. The Echinodermata consisted of *Comatula Sarsii* of Von Duben and Koren, a species new to Britain, but previously obtained by Professor Sars off the Norwegian coast; and a new species of the family *Sipunculidæ*, for which the name of *Phascolosoma radiata* was proposed. The descriptions were accompanied by drawings of the new species, and lists of the rare Mollusca and Zoophytes obtained by Mr. Barlee at the same time were also added.

On Dicoryne stricta, *a New Genus and Species of the* Tubulariadæ. *By* Professor Allman, *M.D., F.R.S.*

The subject of this communication had been recently obtained by the author in the Orkney seas, where it was found investing an old *Buccinum undatum*, dredged from water about three fathoms deep. It was defined by the following diagnosis:—

DICORYNE.

Gen. Char.—Cœnosarc branched, clothed with a polypary and adhering by a tubular network. Polypes claviform, of two kinds, one sterile, the other proliferous, both borne upon the common cœnosarc, and issuing from the extremities of the branches. Sterile polypes with a verticil of tentacula situated behind the mouth; proliferous polypes destitute of tentacula (and mouth?), and having the gonophores clustered round their base.

D. stricta.—Stem rising to the height of about ½ an inch, irregularly branched; branches ascending at a very acute angle from the stem. Polypary slightly dilated at the extremities of the branches, somewhat corrugated near the base, but without distinct annulations. Tentacula about 16 in a slightly alternating verticil.

On Laomedea tenuis, *n. sp.* *By* Professor ALLMAN, *M.D., F.R.S.*

This new species of *Laomedea* was obtained by the author while dredging in the Orkney seas, and was now described with the following diagnosis:—

Stem geniculate; polypiferous ramuli having the same diameter as the stem, springing alternately from the geniculations; the entire stem and ramuli distinctly annulated; polype-cells with deeply-cleft margins; polypes very extensile, with 16 or 18 tentacula. Capsules medusiferous, large, cylindrical, with the proximal end conical, and with the remote end broad and truncated.

On a remarkable Form of Parasitism among the Pycnogonidæ. *By* Professor ALLMAN, *M.D., F.R.S.*

The author described the occurrence on the branches of some species of *Coryne*, of peculiar pyriform vesicles, which might at first sight be easily taken for the reproductive sacs of the zoophyte.

They had their cavity in free communication with the general cœnosarcal cavity of the zoophyte, and an endoderm, ectoderm, and external chitinous investment were easily demonstrable in their walls.

The nature of their contents, however, at once distinguished them from the proper reproductive sacs of the Coryne; for in every instance they enclosed a Pycnogonidan (*Ammothea*?). The included Pycnogonidan was always solitary, and in the smaller vesicles was still embryonic, while in the larger ones it presented an advanced stage of development, and was ready to escape from its confinement by the rupture of the surrounding walls.

On the Structure of the Lucernariadæ. *By* Professor ALLMAN, *M.D., F.R.S.*

In this paper the author described the structure of the *Lucernaria cyathiformis* of Sars, which, however, differed so much from the typical *Lucernaria* as to convince him that it ought to be placed in a distinct genus, for which he proposed the name of *Carduella*.

The central stomach, which the author compared to the manubrium of a gymnophthalmous medusa, has the reproductive system developed in its walls, and eight vertical septa extend from it, converging in pairs to the external walls of the body, to which they are attached by four equidistant longitudinal ridges. These external walls are the exact representative of the umbrella of a medusa, and the author believed that he had succeeded in demonstrating the existence in them of four equidistant longitudinal canals, which run from the base of the cup-shaped body of the animal, to within a short distance of its margin, where they open into a circular canal, into which the tubular tentacles also open.

Prof. Allman endeavoured to show that the structure of *Carduella* was essentially that of a gymnophthalmous medusa, the longitudinal lamellæ by which the little animal might at first sight appear referable to the actinozoal type of structure being totally different in their arrangement and relations from the gastro-parietal lamella of an Actinia.

We have only to conceive of a *Thaumantias*, or similar medusa, with its manubrium united to its umbrella by the development within the latter of the eight septa just described, and we would then have it converted into a *Carduella*, so far as regards the most essential points of its structure.

Descriptions of Genera of Fish of Java. By Dr. Bleeker.

Personal Observations on the Zoology of Aberdeenshire. By S. M. Burnett.

List of Marine Polyzoa, collected by George Barlee, *Esq., in Shetland and the Orkneys, with Descriptions of the New Species. By* George Busk, *F.R.S., F.L.S.*

The number of species collected by Mr. Barlee in the above region, and submitted to my notice, amounts to about forty, of which nine are probably new or undescribed.

Suborder I. CHEILOSTOMATA.

Fam. I. **Salicornariidæ**, Busk.

Gen. 1. Salicornaria, Cuvier.

1. *S. Johnsoni*, Busk. Cellaria Johnsoni, *Busk, Q. J. Micr. Sc.* vol. vii. p. 65 (*Zoophytol.* pl. 22. figs. 4, 5). ? Cellaria marginata, *Reuss* (non *Goldfuss*), *Fossil. Polyp. d. Wien. Tertiärbeck.* p. 59, pl. 7. fig. 29 (*non* 28).

Fam. II. **Cellulariidæ**, Busk.

Gen. 2. Cellularia, Pallas.

1. *C. Peachii*, Busk. C. Peachii, *Busk, Ann. Nat. Hist.* 2 ser. vii. p. 82, pl. 8. figs. 1, 2, 3, 4; *Brit. Mus. Cat.* part i. p. 20, pl. 27. figs. 3, 4, 5.

Gen. 3. Menipea, Lamx.

1. *M. ternata*, Soland. (sp.). M. ternata, *Busk, Brit. Mus. Cat.* part i. p. 21, pl. 20. figs. 3, 4, 5. Crisia ternata, *Lamx.* Tricellaria ternata, *Fleming*; *Blainville*; *Gray*. Cellularia ternata, *Johnston*.

Fam. III. **Scrupariidæ**, Busk.

Gen. 4. Hippothoa, Lamx.

1. *Hippothoa catenularia*, Jameson. H. catenularia, *Busk, Brit. Mus. Cat.* part i. p. 29, pl. 18. figs. 1, 2; *Fleming*; *Hassall*; *Couch*; *Johnston*; *Gray*. Tubipora catenulata, *Stewart*.
2. *Hippothoa divaricata*, Lamx. Hippothoa divaricata, *Busk, Brit. Mus. Cat.* part i. p. 30, pl. 18. figs. 3, 4. *Lamx.*; *Johnston*; *Audouin*. H. lanceolata, *Gray*; *Hassall*; *Couch*; *W. Thompson*. Catenicella divaricata, *Blainv.*

Fam. IV. **Cabereadæ**, Busk.

Gen. 5. Caberea, Lamx.

1. *C. Hookeri*, Busk. C. Hookeri, *Busk, Brit. Mus. Cat.* part i. p. 39, pl. 37. fig. 2. Cellularia Hookeri, *Fleming* (pars); *Johnston*. ? Bicellaria Hookeri, *Blainville*.

The species of *Caberea* originally discovered by Hooker on the south coast is probably identical with *Cab. Boryi*; but that form and the one from the northern seas were confounded together by Dr. Johnston under the same appellation. The specific name, therefore, is hardly in strict language applicable to the northern species, but has been retained (though altered in its precise application) in compliment to the illustrious botanist to whom it was originally given.

Fam. V. **Bicellariidæ**, Busk.

Gen. 6. Bicellaria, Blainville.

1. *B. ciliata*, Linn. (sp.). B. ciliata, *Busk, Brit. Mus. Cat.* part i. p. 41, pl. 34; *Blainville*. Sertularia ciliata, *Linn.* Cellaria ciliata, *Ellis* & *Solander*; *Lamk.* Bugula ciliata, *Oken*. Cellularia ciliata, *Pallas*; *Johnston*; *Couch*; *Gray*. Crisia ciliata, *Lamouroux*; *Templeton*; *Van Beneden*.

2. *Bicellaria Alderi*, n. sp. Cells turbinate, much attenuated downwards; aperture oval, a single marginal spine at the outer angle.
Hab. Shetland (*Barlee*).
The distinctive characters of this species were first pointed out to me by Mr. Joshua Alder, to whom I have dedicated the species.

Gen. 7. BUGULA, Oken.

1. *B. Murrayana*, Bean (sp.). B. Murrayana, *Busk, Brit. Mus. Cat.* part i. p. 46, pl. 59. Flustra Murrayana, *Bean*; *Johnston.* ? Sertularia spiralis, *Olivi.* Flabellaria spiralis, *Gray.*

Fam. VI. Flustridæ, d'Orbigny.

Gen. 8. FLUSTRA, Linn.

1. *F. foliacea*, Linn. F. foliacea, *Busk, Brit. Mus. Cat.* part i. p. 48, pl. 55. fig. 45, pl. 56. fig. 5; *Auctorum.*
2. *F. truncata*, Linn. F. truncata, *Busk, Brit. Mus. Cat.* part i. pl. 58. figs. 1, 2, pl. 56. figs. 1, 2; *Linn.*; *Müller*; *Ellis & Solander*; *Esper*; *Olivi*; *Johnston*; *Blanville*; *&c.* F. securifrons, *Pallas.*
3. *F. Barleei*, n. sp. *F.* polyzoaria foliacea, divisa, lobata; cellulis oblongis, margine simplici; ovicellulis cucullatis; aviculariis inter cellulas sparsis, oblique positis, mandibulo semicirculari.
Hab. Shetland (*Barlee*).
Flustra Barlei, *Busk, Q. J. Micr. Sc.* vol. viii. p. 123 (*Zoophyt.* pl. 25. fig. 4).

Fam. VII. Membraniporidæ, Busk.

Gen. 9. MEMBRANIPORA, Blainville.

1. *M cornigera*, n. sp. *M.* incrustans, cellulis pyriformibus, superne angustatis, margine glabro, spinis 6 erectis armato, quarum infimis bifurcatis; lamina granulosa; apertura magna irregulari; aviculariis crebris inter cellulas sparsis, mandibulo semicirculari.
Hab. Shetland (*Barlee*).
M. cornigera, *Busk, Q. J. Micr. Sc.* vol. viii. p. 124, pl. 25. fig. 2.
2. *M. vulnerata*, n. sp. *M.* incrustans; cellulis subpyriformibus seu subovalibus, superne angustatis; apertura parva semicirculari, lamina granulosa, utroque latere fissura sigmoidea, plerumque ornata; margine granuloso, inermi; vibraculis inter cellulas sparsis.
Hab. Shetland (*Barlee*).
M. vulnerata, *Busk, Q. J. Micr. Sc.* vol. viii. pl. 124, p. 25. fig. 3.
3. *M. minax*, n. sp. *M.* adnata, cellulis pyriformibus, inferne attenuatis; area ovali, apertura trifoliata, lamina glabra; margine tenui spinis elongatis gracilibus armato; aviculario magno, sessili, in parte anteriore cellulæ medio posito, mandibulo rostroque peracuto instructo; ovicellula magna, rotundata.
Hab. Shetland (*Barlee*; on stone).
M. minax, *Busk, Q. J. Micr. Sc.* vol. viii. p. 125, pl. 25. fig. 1.
4. *M. Rosselii*, Audouin (sp.). Flustra Rosselii, *Audouin.* M. Rosselii, *Busk, B. M. Cat.* part i. p. 59, pl. 100. fig. 2.
5. *M. Pouilletii*, Audouin (sp.). Flustra Pouilletii, *Audouin.* M. Pouilletii, *Alder, Cat. of Zooph. of Northumberland and Durham*, p. 56, pl. 8. fig. 5. ? M. membranacea (pars), *Johnston.*
6. *M. spinifera*, Johnston (sp.). M. spinifera, *Alder, l. c.* p. 53, pl. 8. figs. 2, 2*a*. Flustra spinifera, *Johnston.* ? Flustra lineata (pars), *Johnston.*

Gen. 10. LEPRALIA, Johnston.

1. *L. sinuosa*, n. sp. *L.* cellulis subrhomboideis, planis, perforatis, linea elevata sinuosa sejunctis; orificio suborbiculari infra sinuato, peristomate elevato.
Hab. Shetland (*Barlee*; on shell).
L. sinuosa, *Busk, Q. J. Micr. Sc.* vol. viii. p. 125, pl. 24. figs. 2, 3.
2. *L. Barleei*, n. sp. *L.* cellulis ovoideis, convexis, superficie granulosa; orificio

orbiculari, infra sinuato; peristomate simplici, elevato; ovicellulis decumbentibus, ad marginem supra perforatis.
Hab. Shetland (*Barlee*; on shell).

3. *L. canthariformis*, n. sp. *L.* cellulis late ovoideis, superficie granulosa punctata nitida; orificio magno, suborbiculari seu irregulari, peristomate producto infundibuliformi integro circumdato.
Hab. Shetland (*Barlee*; on shell).

4. *L. umbonata*, n. sp. *L.* cellulis oblongis, seriatis, linea elevata sejunctis, ad latera perforatis, medio umbonatis et juxta orificium avicularium mandibulo semicirculari horizontali gerentibus; orificio suborbiculari, infra paullulum constricto, peristomate simplici, spinis 4 supra armato; ovicellula umbonata vittaque parva utrinque ornata.
Hab. Shetland (*Barlee*; on stone).

5. *L. Malusii*, Audouin (sp.). L. Malusii (var. spinata), *Busk, Brit. Mus. Cat.* part i. p. 83, pl. 103. figs. 1, 2, 3, 4; *Q. J. Micr. Sc.* vol. viii. p. 125 (*Zoophyt.* pl. 24. fig. 1). L. biforis, *Johnston.* Eschara Malusii, *Audouin.* Cellepora Macry, *W. Thompson.*

6. *L. Pallasiana*, Moll. (sp.). L. Pallasiana, *Busk, Brit. Mus. Cat.* part i. p. 81, pl. 83. figs. 1, 2. L. pedilostoma, *Hassall.* L. pediostoma, *Johnston*; *Couch.* Cellepora Pallasiana, *Lamx.* Eschara Pallasiana, *Moll.* Flustra hibernica, *Hassall.*

7. *L. labrosa*, Busk. L. labrosa, *Busk, Brit. Mus. Cat.* part i. p. 82, pl. 92. figs. 1, 2.

8. *Lepralia bispinosa*, Johnston. Lepralia bispinosa, *Johnston, Brit. Zooph.* ed. 2. p. 326, pl. 57. fig. 10; *Busk, Brit. Mus. Cat.* part i. p. 77, pl. 80. figs. 1, 2, 3, 4.

9. *L. granifera*, Johnston. L. granifera, *Johnston, Brit. Zooph.* ed. 2. p. 309, pl. 54. fig. 7; *Busk, Brit. Mus. Cat.* part i. p. 83, pl. 87. fig. 2, pl. 95. figs. 6, 7.

10. ?*L. Landsborovii*, Johnston. L. Landsborovii, *Johnston, Brit. Zooph.* ed. 2. p. 310, pl. 54. fig. 9; *Busk, Brit. Mus. Cat.* part i. p. 66, pl. 86. fig. 1, pl. 102. fig. 1.

11. *L. ringens*, Busk. L. ringens, *Busk, Q. J. Micr. Sc.* vol. iv. p. 308 (*Zooph.* pl. 9. figs. 3, 4, 5).

Gen. 11. Alysidota, Busk.

1. *A. Alderi*, Busk. A. Alderi, *Busk, Q. J. Micr. Sc.* vol. iv. p. 311 (*Zoophyt.* pl. 9. figs. 6, 7).

2. *A. conferta*, n. sp. *A.* cellulis confertis ovoideis, punctatis; orificio parvo, orbiculari, infra emarginato, peristomate subincrassato, spinis 4 armato; ovicellula recumbente, subimmersa, punctata.
Hab. Shetland (*Barlee*; on stone).

Suborder II. CYCLOSTOMATA.

Fam. I. Crisiidæ, M.-Edwards.

Gen. 1. Crisia, Lamouroux.

1. *C. aculeata*, Hassall. C. aculeata, *Johnston, Brit. Zoophyt.* ed. 2. p. 285; *Hassall.* C. eburnea (pars), *M.-Edwards*; *Van Beneden.*

Fam. II. Idmoneidæ, Busk

Gen. 2. Idmonea.

1. *I. atlantica*, E. Forbes. I. atlantica, *Johnston, Brit. Zoophyt.* ed. 2. p. 278, pl. 48. fig. 3; *Busk.*

Gen. 3. Pustulopora, Blainville.

1. ? *P. proboscidea*, F. Forbes.

Fam. III. Tubuliporidæ, Busk.

Gen. 4. Tubulipora (pars), Lamarck.

1. *Tubulipora truncata*, Jameson (sp.). T. truncata, *Johnston, Brit. Zoophyt.* ed. 2. p. 271, pl. 33. figs. 8–10; *Busk*; *Fleming.* Millepora truncata, *Jameson.*

Fam. IV. Diastoporidæ, Busk.

Gen. 5. ALECTO, Lamx.

1. *Alecto major*, Johnston. A. major, *Johnston, Brit. Zoophyt.* ed. 2. p. 281, pl. 49. figs. 3, 4.
2. *A. granulata*, M.-Edwards. A. granulata, *Johnston, Brit. Zooph.* ed. 2. p. 280, pl. 49. figs. 1, 2.

Gen. 6. DISCOPORELLA, Gray.

1. *D. hispida*, Fleming (sp.). Tubulipora hispida, *Johnston*; *Busk*. Discopora hispida, *Fleming*.

Gen. 7. PATINELLA, Gray.

1. *P. patina*, Lamarck (sp.). Tubulipora patina, *Lamarck*; *Johnston*; *Risso*; *Blainville*; *&c.*

Suborder III. CTENOSTOMATA.

Fam. I. Farrellidæ, Busk.

Gen. 1. AVENELLA, Dalzell.

1. *A. fusca*, Du Gell. Farrella fusca, *Busk*.

Gen. 2. BUSKIA, Alder.

1. *B. nitens*, Alder. B. nitens, *Alder, Zoophytes of Northumberland & Durham*, p. 66, pl. 5. figs. 1, 2; *Busk*.

Remarks on the Mollusca of Aberdeenshire. By Dr. DICKIE.

These remarks are founded on the investigations of the late Professor Macgillivray, and my own observations.

The Mollusca of Aberdeenshire comprehend representatives of all the British families, excepting eleven; the species amount to two hundred and thirty.

Although some objections have been urged against the types into which the British species are divided in Forbes and Hanley's 'Mollusca,' they, however, afford a useful scale of comparison, as to distribution on different parts of the coast of the United Kingdom.

Of the *Lusitanian* and *S. British* types, the best-marked example found here is *Trochus crassus*, which is rare. The *European* type is well represented; but some species, very abundant in more southern and western districts, are rare at Aberdeen. The *Celtic* type, like the last, is general, but principally distributed toward the north: many of its species are abundant at Aberdeen; but some are rare, as *Chiton ruber* and *Pholas candida*. The *British* type consists of a few species most abundant in, or confined to Britain: two of these are frequent on this coast, viz. *Trochus millegranus* and *Pecten tigrinus*; *Astarte triangularis* and *Scalaria Trevellyana* are rare. The *Atlantic* branch is very partially represented here; and the few species which occur are rare. The *Boreal* type does not comprehend many species; but most of them are found on our coast, and are generally abundant, as *Astarte compressa*, *Acmæa testudinalis*, *Cyprina Islandica*, *Trochus helicinus*, *Velutina flexilis*; others are rare, as *Astarte elliptica*, *Puncturella Noachina*, &c. Those designated as truly *Arctic* in the British list are few; none have hitherto been found here.

Our mountains are singularly deficient in land- and freshwater-species; I have only seen three at any great elevation. *Pisidium pulchellum* occurs at 1742 feet, along with *Limneus pereger*, the shell of the latter being very thin and fragile, and the tip of the spire usually defective; the *Pisidium* is also found at 2400 feet. The other species observed above 1000 feet is *Arion ater*, viz. at 1874 feet, the individuals being large, and the colour well-developed.

It may, finally, be worthy of record here, that *Panopæa Norvegica* and *Tellina proxima* occur in the glacial clay in Belhelvie.

On the Structure of the Shell in some Species of Pecten. By Dr. DICKIE.

The following brief statement of facts is not brought forward with any intention of calling in question the more important conclusions regarding shell-structure in

Mollusca, recorded in the Transactions of the British Association for 1844 and 1847, but merely with the view of showing what caution is necessary in drawing conclusions from some of the instances recorded there.

It is stated that, in Pectinidæ, "corrugated membranous structure with tubular structure is sufficient to distinguish a shell of this family from any neighbouring family to which in general characters it might possess an affinity;" allusion is also made to traces of cellular structure on the outside, a thin layer having been observed in *Pecten nobilis*; it is conjectured that the rarity of such cellular layer may be owing to abrasion during the active movements of the animals; the examination of very young specimens is also recommended.

While preparing some specimens illustrative of shell-structure for class demonstration, I found that the *Pecten vitreus* (*P. Grœnlandicus* of some authors), an Arctic species, the shell of which is singularly transparent, is well-suited for such purpose, and has some peculiarities which seem deserving of record. Both valves have a thin layer of membranous structure inside; the whole of the convex valve has tubular tissue on the outside: the body of the flat valve, on the other hand, is distinctly cellular, while the auricular portion is tubular. The convex valve, therefore, has the characters assigned in the Report above quoted; while the flat presents three kinds of tissue, in different parts of it,—viz., membranous, tubular, and cellular. Specimens of different ages were found presenting the characters above stated. It is obvious, therefore, that erroneous conclusions would result from any partial examination of this species.

I was further induced to examine young individuals of a native species, *Pecten maximus*; specimens half an inch or even an inch broad are transparent enough for the purpose. Here it is the convex valve which is cellular on the outside, and not the flat valve (as in *Pecten vitreus*); for it has on the outside an obscurely tubular structure with numerous granules interspersed. Of *Pecten similis*, which is very translucent, I had only a few separate valves at disposal: some of these I found to be cellular, and others obscurely tubular on the outside.

In the Report already quoted, an example is given, illustrative of the importance of shell-structure in determining affinities. A fossil was described by Professor Phillips as an *Avicula*, and by Messrs. Young and Bird as a *Pecten*; the mixture of external characters is such as would sanction its being placed in either genus. From the absence of cellular or membranous structure, which characterizes *Avicula*, and the presence of corrugated and tubular tissue, it was inferred that this fossil ought to be placed in Pectinidæ: the facts above recorded seem to require a revisal of such decisive conclusion.

On the Varieties and Species of New Pheasants recently introduced into England. By John Gould, *Esq., F.R.S. &c.*

After a sketch of the distribution of the family of Gallinaceous birds, the author gave an account of the species of the genus *Phasianus* (Pheasants) which had been introduced into England. All the species were from Asia. The oldest-known was the *P. Colchicus* from Asia Minor; the next was *P. torquatus* from Shanghai, which was introduced about one hundred years ago, and had recently been reintroduced; and the third was *P. versicolor*, from Japan. The crosses between these three species produced remarkably fine, strong and heavy birds. The other true species exhibited was *P. Mongolicus*, from Mongolia. Mr. Gould also placed on the table specimens of *P. Sœmmeringi* from Japan, and *P. Reevesi* from China, a bird remarkable for having a tail 6 feet in length.

Mr. Gould exhibited several species of Birds of Paradise, for which he was indebted to Mr. Wallace, who had recently procured numerous fine examples of several members of this beautiful family, and had moreover discovered a splendid new bird (perhaps allied to this group), which had been named, in honour of him, *Semioptera Wallacei*. The species exhibited were, *Paradisea apoda* from Arru Island; *P. Papuana* and *P. rubra*, *Diphyllodes magnifica*, *Parotia aurea*, and *Cicinnurus regius* from New Guinea; and the new *Semioptera Wallacei* from the island of Batchian.

On some New Species of Birds. *By* JOHN GOULD, *Esq., F.R.S. &c.*

Account of a Species of Phalangista recently killed in the County of Durham. *By* JOHN HOGG, *M.A., F.R.S., F.L.S. &c.**

On the 22nd August last, the Rector of Redmarshall sent to the author at Norton, in the county of Durham, a recently killed and singular-looking animal. On a slight examination of it, he found that it was a New South Wales species, like an *opossum*; but being a *male*, it had no *marsupium*, or pouch. As that village is far from any town, it had evidently escaped from confinement; it had been killed the evening before, whilst it was upon a poplar-tree on a farm near Redmarshall. The farmer, when he first saw it, observed it following some hens, and, fearing their destruction, pursued and at length killed it.

The following is the description which Mr. J. Hogg gave of it:—The length from the tip of the nose to the base of the tail, $18\frac{3}{4}$ inches; the length of the tail, about 13 inches; entire length, $31\frac{3}{4}$ inches.

The dentition is as follows:—Two large front teeth, or *incisors*, in the *lower* jaw, somewhat curved inwards, like those of rabbits, squirrels, &c.; six *incisors* in the *upper* jaw, then two small *canines*, of which the *first* is much larger than the *second*; and four or five *molars*. The last could not be determined, as the animal was stiff, and the author did not like to force the jaws open. In the *lower* jaw are *no canines*, but four or five *molars*, most likely *five*. Hence the *formula*—

	Inc. C. M.
For the *upper* jaw	6+4+10=20 in all;
For the *lower* jaw	2+0+10=12 in all;

these make together 32 *teeth* in all. Legs rather short, *front* foot with five toes and five long curved claws. But the *hind* foot has only two large toes and two claws, also a *third* toe divided into *two* as far only as the last *phalanx*; or at least the *two* are *united* by the skin *up to that* phalanx; and they have both long claws. Then beyond again, and placed more backward, is a large and broad thumb, though *without* any claw or nail. The *feet* are evidently those of a *climbing* animal; and the *tail* also is *prehensile*, for it is curved inwards at its tip, and without hairs *under* that portion. The skin on each side in the flank, from about the middle of the belly to the hind legs, being loose and somewhat extensible, seemed to show some *rudiment* of the loose *lateral skin* so conspicuous in the *flying opossum*.

In colour, the upper portion of the body is greyish, or dusky white, mixed with some red and black hairs; the neck, breast, and belly are *yellow*, with a *rusty-red* line down the breast, which extends under the fore legs. Tail thick, hairy; the lower two-thirds being black; insides of the ears nearly bare of hairs; length from the nose to the ear about $3\frac{1}{4}$ inches, and the ear about $2\frac{3}{4}$ inches long, and in the middle $1\frac{3}{4}$ inch wide. This *male* specimen was clearly full-grown, but the teeth were not much worn, and the claws very sharp.

The description of the *vulpine opossum* in Bewick's 'History of Quadrupeds' (edit. 4, 1800), p. 435, seemed to agree in most particulars, and that species to correspond with that named in Cuvier's 'Règne Animal,' "le Phalanger Renard" (*Phalangista vulpina*). As Bewick had given no wood-cut of the former animal, the author could not decide whether it is *that* species, or another described as *P. fuliginosa*, or the "Sooty *Phalangista*," to the description of which it corresponds in several points.

As some of the *Phalangistæ* are eaten by the natives of Australia, and as many live on fruits, and leaves, and shoots of trees, Mr. Hogg inquired of the animal-preserver, who stuffed it, if the flesh was dark-coloured; but he stated that it was not unlike that of a rabbit. The specimen was plump, and looked as if it had fed well during its rambles; and the author was sorry that he neglected to have the contents of the stomach examined.

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List of the Birds of the North of Scotland, with their Distribution. *By* T. F. Jamieson.

A detailed list was given of the birds found in that part of Scotland lying to the north of the Firths of Forth and Clyde, showing the distribution and comparative frequency of each species. The whole number amounted to 258, of which 106 remain throughout the whole year, 37 are summer visitors that breed in the region, 38 are winter visitors, 5 visitors during the vernal and autumnal migrations, 67 stragglers from England and Europe, 4 stragglers from America, and 1 straggler from Asia.

Some species have been extinguished in recent times, viz. Capercailzie, Bustard, Bittern, and great Auk; while the Eagles and larger Hawks have become exceedingly scarce, and are banished from most districts. Those species that haunt waste lands and marshes are also diminishing in numbers; on the other hand, the denizens of cultivated tracts are on the increase.

The Goldfinch has become much rarer than formerly, while the Missel Thrush seems spreading and more numerous, and the Woodcock now frequently remains all summer.

Dr. Lankester exhibited a series of drawings from life of the various species of British spiders by Mr. Tuffen West, intended to illustrate Mr. Blackwall's forthcoming work on British Spiders, to be published by the Ray Society. Dr. Lankester solicited contributions of living spiders, which might be sent by post, to enable Mr. West to continue his sketches from life.

Notice of a Skull of a Manatee from Old Calabar. *By* Jas. M'Bain, *M.D., R.N.*

The skull of a Manatee which I now exhibit to the Zoological Section of the British Association was handed over to me a short time ago by Mr. Wm. Oliphant, Treasurer to the Royal Physical Society of Edinburgh. It was transmitted to Mr. Oliphant, from Old Calabar, by Mr. Archibald Hewan, Medical Missionary to the United Presbyterian Mission on the West Coast of Africa—one of those intelligent men, who, in addition to the benevolent object of their calling, lose no opportunity of making contributions to the general stock of scientific information.

The occipital bone, petro-mastoid, and tympanic bulla are wanting,—a part of the basi-occipital, firmly united to the basi-sphenoid, only remaining; the skull is otherwise in a good state of preservation.

Viewed from behind, the anterior half of the internal vaulted cavity of the cranium is seen to be divided into two lateral halves by a curved spinous ridge or crista interna, formed partly by a coalescence of the inner tables of the parietal and frontal bones, but chiefly by the largely developed crista galli of the ethmoid, which extends backwards nearly as far as a depression that appears to represent the sella turcica. On each side of the crista galli there is an oblong depression nearly an inch in length, with several openings, forming the cribriform plate of the ethmoid bone. A slender spinous process bounds the outer edge of the cribriform plate, passing downwards and backwards to terminate over the middle of the foramen lacerum orbitale. Immediately to the inner side of the foramen lacerum orbitale, there is a small aperture which corresponds in position to the foramen opticum; and a little to the outer side there is another foramen, somewhat larger, which probably represents the foramen ovale. There is also a small foramen nearly midway between the cribriform plate and the so-called foramen opticum. From each of these foramina, a distinct groove proceeds backwards, strongly marked behind the foramina lacera. The inner cavity of the cranium is otherwise remarkably free from inequalities, and the sutural connexions are clearly defined.

The cranio-facial bones are mounted on the massive lower jaw, at a height of rather more than six inches, and slope forward at an angle of nearly 45°. A plumb-line, dropped from the posterior centre of the parietal bone to a level with the angular processes of the lower jaw, measures $9\frac{1}{2}$ inches. The distance across from the outer edge of each zygomatic arch is $9\frac{3}{10}$ inches, nearly four inches of this space being occupied by the cranial cavity. The pterygoid wings are large and strong, three inches in length, with a rough outer ridge behind, the under points reaching to a level with the alveolar grooves of the inferior maxillæ; and there is a distinct hamular process, somewhat resembling a finger-nail, at the under and inner edge. The squamous part of the temporal bone, with its largely developed zygomatic process, abuts against the under edge of the parietal and ali-sphenoid.

The length of the zygomatic arch is $5\frac{4}{10}$ inches, the depth fully 2 inches. The glenoid surface is formed by a slightly raised, tuberculated, convex eminence, about an inch and a half in length, and half an inch across, placed obliquely at the under and fore part of the root of the zygoma. At the posterior and inner part of the root of the zygomatic arch, there is a deep, smooth, ovate cavity for the support of the petro-tympano-mastoid bones.

The malar bone is seven inches in length, and extends from the outer edge of the glenoid surface to the anterior margin of the orbital fossa. It is formed by a narrow zygomatic process behind, on which the posterior two-thirds of the zygoma rests. It gradually expands upwards, downwards, and forwards, into a broad maxillary process, terminating in a twisted curved orbital plate, which forms the outer part of the floor of the orbital cavity, and overlaps a part of the orbital process of the superior maxillary bone. The superior orbital process of the malar bone projects in the form of a mammillated protuberance, with a deep fissure where it rises from the maxillary process, and inclines towards the post-orbital process of the frontal bone, being separated from the latter by an open space $\frac{3}{10}$ths of an inch at the outer posterior boundary of the orbital cavity. The temporal fossa is four inches in length, reaching as far forwards as the fifth molar tooth, counting from before backwards. The upper coronal surface measures $5\frac{1}{2}$ inches from the parietal ridge to the tip of the nasal process of the frontal bone, and about an inch and a half across. It is concave above, with a longitudinal ridge on each side diverging in front into two orbital processes, at first somewhat narrow, where they bound the upper and fore part of the temporal fossa, then expanding into broad thick plates, convex above and concave beneath, forming the roof of the orbits. The distance from the tips of the premaxillary bones to the anterior margins of the orbits is 4 inches. The orbital cavities extend obliquely outwards, forwards, and downwards, the inner part of the floor being formed by the broad, thick, bridge-like orbital plate of the upper maxillary bones, having a large oval inferior orbital canal opening directly in front. The premaxillaries are united anteriorly by a mystachial suture $2\frac{3}{10}$ inches in length, and extend backwards on each side of the anterior nasal fossæ, by a narrow process, to a little behind the fore part of the orbits. They are here connected by suture to an elongated squamous cancellated bone, two inches in length, and two-thirds of an inch across, which I shall call the nasal bone. At the middle of the nasal bone, corresponding to the points of union between the upper maxillary and frontal bones, forming the inner border of the orbits, the anterior nasal fossæ expand to four inches in width, and $5\frac{7}{10}$ inches in length, becoming narrower both above and below. The premaxillaries are compressed in front, and form, along with the anterior part of the upper maxillary bones, a short narrow muzzle, $2\frac{1}{2}$ inches in length, bending downwards beak-like, at an angle approaching to thirty degrees. The palate plates of the premaxillaries, anterior to the large single foramen incisivum, are about an inch in length, the same in breadth, with two socket-like depressions on each side, the two in front rather larger than those behind, which appear to have contained four deciduous incisor teeth. The length of the palate of the skull, from the incisive border of the premaxillaries to the posterior curved edge of the palate-bone is $8\frac{1}{2}$ inches, and the breadth about an inch. From the curved edge of the palate bone to the ridge marking the union of the basi-occipital to the basi-sphenoid, the distance is 3 inches, making the total length of the base of the skull to this point $11\frac{1}{2}$ inches.

An oval opening, an inch and a half deep, and rather less in width, forms the posterior nasal aperture. It is bounded beneath by the palate plates of the palate bones, which consist of two narrow pointed processes divided by a fissure behind, and extending forwards about an inch, where the two small posterior palatine foramina are situated, but which appear to be chiefly formed in the palate-plates of the superior maxillary bones. The nasal plates and pterygoid processes of the palate bones form the walls of the posterior nares. The pterygoid processes extend outwards and backwards, are twisted over and nearly cover the two posterior alveoli.

The lower jaw is a dense massive bone, the sides forming a right angle with the broad flat vertical rami. The length of the sides from the incisive edge to the angle of the jaw is fully 8 inches, and the depth about $2\frac{1}{2}$ inches. The perpendicular height of the rami from the angle of the jaw to the condyle is $6\frac{7}{10}$ inches; and from the condyle to the anterior point of the coronoid process, the distance is 4 inches, the upper border of the coronoid being nearly on a level with the condyle. The symphysis at the fore and under part of the two rami is $3\frac{1}{2}$ inches in length, with a large grooved foramen menti and another foramen behind, which communicates with the maxillary canal. The upper anterior incisive portion is $2\frac{1}{2}$ inches, having a rough, pitted, irregular surface. A special peculiarity marking the lower jaw is the acute inflected angle, the distance between the two inner points of the angles being only $3\frac{2}{10}$ inches. The alveolar process of the lower jaw is seven inches in length, slightly curved outwards and downwards anteriorly. There is another curve outwards and upwards at the posterior termination, where it protrudes by an inflated extremity through the inner part of the root of the coronoid process, directly above the posterior maxillary foramen.

Eleven molar teeth, with two large transverse bi-tuberculated ridges, and a smaller ridge behind, are implanted by two roots in sockets about an inch deep, on each side of the lower jaw. The roots of the teeth are flattened transversely, corresponding to the transverse coronal ridges. The anterior root is curved backwards, longer and more fully developed than the posterior one, and penetrates the inner alveolar wall in several places. The roots of the molars in front are solid and bifurcated at the apex; whilst those behind have the roots of nearly equal length, and are hollow at the apex. The molar teeth in the upper jaw have two transverse tri-tuberculated ridges, with a ridge-like thickening of the cervix anteriorly and posteriorly. Each tooth has three slightly diverging roots, the inner root compressed longitudinally, the two outer roots compressed transversely; and the external anterior root is also curved backwards like the corresponding one of the lower jaw. Only the eight anterior molar teeth have been in use for mastication, the three posterior being nidamental; and the points of the foremost two or three molars are much worn down, showing a thin dark outer layer of cement, succeeded by a thicker coat of enamel, which surrounds a light-brown dentine.

This skull agrees with the brief descriptions which I have seen of the "*Manatus Senegalensis*;" and the locality whence it was derived confirms this view. Skulls of this species, however, appear to be rare in our public museums; for there are none described in the Catalogue of the Royal College of Surgeons of London, and none in that of the British Museum, as existing in either of these valuable osteological collections.

In the British Museum Catalogue for 1850, the number of grinders in the genus Manatus is said to vary according to the age or state of the specimens, but when complete they are $m\,\frac{9-9}{9-9}$. It is stated that the front ones are often deciduous; hence Sir E. Home describes them as $m\,\frac{6-6}{6-6}$, and Cuvier as $m\,\frac{8-8}{8-8}$. In this skull, the teeth are well preserved,—39 remaining in their sockets, and 5 distinct empty sockets for others. The dental formula is therefore $m\,\frac{11-11}{11-11}=44$.

Notice of the Duration of Life in the Actinia Mesembryanthemum *when kept in confinement. By* Dr. M'Bain.

Notice of the Skull of a Wombat from the Bone-Caves of Australia. By Dr. M'Bain.

Notice of the Skull of a Seal from the Gulf of California. *By* Dr. M'Bain.

On the Classification of the Salmonidæ. *By* R. Knox, *M.D.*

On a New Species of Galago (Galago murinus) *from Old Calabar.* *By* Andrew Murray, *Edinburgh.*

After giving some details regarding the habits of this Galago, which he had received from his correspondent, the Rev. W. C. Thomson, one of the United Presbyterian missionaries stationed in Old Calabar, and pointing out its specific distinctions, the author took the opportunity of discussing the value of the characters of the convolutions of the brain and its extension over the cerebellum, recently brought prominently forward by Prof. Owen as of primary importance in the classification of the mammifera, as exhibited in the osculant group of the Quadrumana to which the *Galago* belongs. The conclusion to which he arrived was confirmatory of the views of Prof. Owen: like him, he considered the insectivorous monkeys an exception to the general rule drawn from the convolutions of the brain (without disparaging that character), and would retain them among the Quadrumana, unless indeed a separate tribe should be erected for their reception—which the other characters of the internal structure scarcely seemed to justify, notwithstanding the external peculiarities of these animals, which partake of the bat, of the squirrel, of the hedgehog, &c., as well as of the monkey.

On the Habits and Instincts of the Chameleon. *By* W. E. C. Nourse, *F.R.C.S., Fellow of the Royal Medical and Chirurgical Society.*

When travelling in Nubia with a friend, we procured seven chameleons. Their prevailing colour was a bright delicate green. Occasionally, they turned dark, some more frequently than others; and when irritated, as by tickling or interfering with them, they first came out all over in spots, then turned dark, at the same time arching the back, inflating the body, opening the mouth very wide, and puffing at the intruder, or trying to bite. If they got a finger into their mouths, they had power enough to give it a smart pinch, but not to cut the skin.

Two of the chameleons were brought to us damaged or sickly; their green was very pale, and their skin soft and flabby. One soon died. The other lingered nearly a fortnight, and cast its skin; this one was always covered with dark spots like a leopard, and never changed colour. Of the remaining five, two got away, and two more died from eating spiders. They first showed signs of torpidity, keeping one eye closed, then became puffed up, and lost power in their limbs; and their skin, of a very pale green, got soft and flabby, while a great oval black patch developed itself on each of their sides; and they died in from twenty-four to forty-eight hours after eating the spiders. These black patches were not mortification, nor yet any change of colour in the skin. The skin, on being removed, was colourless; the subjacent muscles there were black; and the small intestines, which lay against them, were filled with black matter like treacle. Thus in three weeks we had only one chameleon left. This was a very large one, $11\frac{1}{2}$ inches long from the tip of his nose to the end of his tail. We had also given him a spider or two; and for some days he seemed torpid and unwell, keeping one eye closed; but after feeding him with flies, twelve to eighteen in a day, and occasionally a little atom of raw meat, he got well and active, and fed himself. His way of feeding was this. On warm days he would begin early in the morning, his time appearing to depend entirely on the degree of power of the sun. As soon as the sun was well up, if put in a window with flies, he would begin eating them, generally yawning and rubbing his nose against his perch after every three or four. In about half an hour he would have eaten twenty-one or twenty-two flies, as I often counted; and would then begin to walk about. The rest of the day he would alternately walk and rest, picking off a fly occasionally when in the humour. Perhaps he might eat thus eight or ten more; but I never saw him take more than one grand feed in the day; so that his average might amount to thirty or thirty-five flies a day. He never seemed to wish for water, but rather disliked it—if dropped into his mouth, he showed signs of distress, and it sometimes oozed out through the nostrils, the palate being cleft; the skin was dry and perfectly free from perspiration or moisture: and from these facts, and the absence of any liquid evacuation, and the rainless climate of Nubia where we got them, I am inclined to think the chameleon never drinks, but that the moisture contained in the bodies of the flies he eats is sufficient for the purposes of his economy. An evacuation was observed to occur every second or third day, usually during the morning feed. On cool days he would wait till noon, or even later, for his feed.

It is not easy, in dissecting the tongue, to make out its length. I have frequently seen this large chameleon take flies six inches from him; in several instances it seemed *at least* seven or eight inches; and the shortest distance was about an inch and a half. The flies were invariably taken with the tongue, which very seldom missed its aim. The movement is very rapid, so that one cannot be certain of its precise nature; but it appears as if the red fleshy tip of the tongue, covered with thick glutinous mucus, made the fly stick to it. The tongue, thus thrust forth, appears, in a full-sized chameleon, to be a cylindrical fleshy organ as thick as a swan's quill. Before making a dart, you may observe that one of the eyes, wandering about, catches sight of the fly at convenient striking-distance, and fixes eagerly upon it; and the other eye instantly converges, as if the animal were squinting; then the mouth slowly opens, the tongue is darted, and the chameleon chops up the insect apparently with infinite relish. Our smallest chameleon could shoot out the tongue to a distance of four inches.

These animals, leaving the damaged ones out of the question, were of different dispositions. Two of them, inclined to be frequently dark-coloured, were very active, wild, and shy, always trying to get away, always hiding themselves, and biting and puffing at the least approach; the other three were more generally green and quiet, less shy and wild. The chameleon, therefore, though a very stupid animal, still possesses certain psychical endowments. Different specimens also differ in their degree of vital power, and in their nervous irritability, with which latter the tendency to change colour is closely connected.

This animal's media of communication with the outer world seem few and imperfect. The eye is the organ on which it most depends; and each eye being capable of independent action, and both projecting so as to have an immense range—directly backwards, forwards, upwards, downwards, and outwards—the chameleon has in some respects double the amount of power of vision possessed by creatures, the action of whose eyes is consentaneous. The eyeball is, however, so closely covered up with opake green lid, that a very small aperture only is left, and nothing can be seen but what is *directly before* the eye. Hearing appears to be nearly or quite absent, as we often proved by experiment; and smell is totally wanting. Taste seems doubtful; what there is seems to reside in the tongue, mostly at the tip; but whether it be true *taste*, or merely such refined sensibility as serves the animal to distinguish a fly from anything else, I know not. When he opens his mouth to bite, he will close his jaws upon your finger, but not on any other substance you may insert; so that there is some sense sufficiently acute to discriminate thus much.

We procured several more chameleons in Alexandria, and brought them to England. A passenger on board the ship had a chameleon from the East Indies. This creature was larger and coarser-looking than the Egyptian specimens, the skin-plates larger, and the green colour duller and coarser. It was fed every day upon one or two little bits of raw meat, each about the size of a fly, and seemed to do very well upon this diet. We therefore adopted the same plan with our Egyptian chameleons; but they gradually pined away and died—the smallest and youngest first, then the old ones, some on board ship, the remainder after landing; so that in a few weeks not one survived.

These chameleons, like those from Nubia, differed in disposition; one was timid, another obstinate, another pugnacious, and so on. When two of equal size happened to meet upon the same perch, as they slowly strode along it, they would stop with their noses about an inch apart, their eyes would converge till they stared one another full in the face, they came out all over in spots like a leopard, then turned nearly black, at the same time arching their backs and bellies, and flattening in their sides, till they assumed the shape of a couple of flounders; then they butted at each other with their noses, and tried, in a weak, harmless way, to knock one another off the perch, until one or both got tired and retreated.

On the Zoophytes of Caithness. By C. W. Peach.

The author commenced by extolling the utility of local catalogues of Natural History, and stated that he was desirous of showing how rich the Scottish shores were in these lovely gems. He then mentioned Mr. J. Macgillivray's list, the result of about three weeks' examination on the Aberdeen coast, as the only Scottish one he had (it contained 64 species), and then proceeded to compare his own with those of Couch's for Cornwall and Alder's for Durham and Northumberland; the former contains 124 species, the latter 164, thus giving a preponderance of 40 species to Alder's. Mr. A. formed his comparison from the List of Cornish Zoophytes published by the Royal Institution of Cornwall: therefore it is not correct; for since that was published, very many have been added both by the author and others, so that he believed the difference, when these were taken in, would be very small. He enumerated his 150 species; and thus a balance of 14 only is left against Caithness, &c. He believed this will soon be reduced when greater attention has been paid to the freshwater ones and the more obscure forms, and when the dredge has been used *; for hitherto all had been collected between tide-marks and from the refuse of the fishermen's lines, and all (with the exception of *Plumularia myriophyllum*, at Peterhead, by the Rev. Mr. Yuill) by himself and sons: the greatest number of southern forms being found at Wick as well, the Wick list is a little the longest. A few forms found at Peterhead are wanting at Wick, and *vice versâ*. The specimens were exhibited, and the greater part presented to Marischal College Museum.

Notes on Different Subjects in Natural History, illustrated by specimens. By C. W. Peach.

Marine Animals.—Mr. Peach placed on the table specimens of marine animals from the Caithness coast and other places. Amongst them was a fine specimen of "Yarrell's Blenny," found by his son Benjamin in a rock-pool near Ackergill Castle; also a pretty one of the "Corkwing," *Crenilabrus Norwegicus*, obtained by his son Joseph in Scapa Bay, Orkney. Although often taken in Cornwall and Devon, it is not noticed in Yarrell's second edition of the 'British Fishes' as having been found further north than the Firth of Forth. Prof. Nilsson considers it common on the coast of Norway and in the Baltic; hence its specific name *Norwegicus*. The most intereresting specimen exhibited was the nest of an Annelide, *Pontobdella*. This worm is parasitical on Rays. The nidi were attached to an oyster-shell which came from the Firth of Forth, and attracted the notice of R. Boyd, Esq., Collector of Customs at Wick, and was kindly sent to the author by him. Fortunately, on examination, the young were found enclosed in the capsule-like nest, and in so perfect a form that the genus and species could be determined. A special interest attaches to this, from so little being known of the early stages of Annelides. There were several other interesting objects exhibited, especially a splendid specimen of Sponge, *Halichondria palmata*, from the Pentland Frith. The author presented Yarrell's Blenny, with the sponge and several of the objects exhibited, to the Museum of Marischal College.

On the Genus Cydippe. *By* John Price, *M.A.*

The author attributed the little acquaintance with that beautiful creature *C. pileus* to the frequent disappointment experienced in attempts to domesticate it. He had himself succeeded in keeping them alive and well for thirteen months, long before the invention of the "aquarium" proper. The first and most essential point is to catch *perfect* specimens. He recommended for this the use of a tin ladle having the mouth quite in the side, that the attempt should be made in a calm only, and that

* Since this paper was read, the author has added four others, and the pretty anemone *Corynactis viridis* which he got at Stroma; it is the first time he has seen it on the Scottish shore.

those should be selected among the specimens, whose trains are already retracted. When deposited in the aquarium undamaged, *C. pileus* thrives remarkably well, and is one of the most joyous of creatures in confinement. Its natural food is prawns, and a rarer kind of shrimps—not the common shrimp. *Beroë* is the natural food of *Cydippe*; but if placed in the same vessel, the interesting spectacle will be afforded of the deglutition by one transparent animal of another equally pellucid.

On the Distribution of British Butterflies. By Mr. H. T. Stainton.

Among the insect tribes, the 'Scale-wings,' or order Lepidoptera, has always attracted a considerable amount of attention; the variety and beauty of the butterfly tribe is a matter of notoriety. The order Lepidoptera includes two great divisions, butterflies and moths; the former group all fly by day, whereas most of the moths are nocturnal in their habits. It has been calculated that there are not less than 50,000 different species of Lepidoptera on the globe. More than 3000 species of butterflies are already known; and it has been computed that the moths are sixteen times as numerous.

In this country the proportion of moths is much greater, being nearly thirty to one; but then we are remarkable throughout Europe for our poverty in butterflies. As already observed, in the whole world 3000 species of butterflies are already known; of these only one-tenth occur in Europe, the tropical parts of Asia and America being by far the most numerously populated with this beautiful tribe of insects.

In central Europe or Germany 186 species of butterflies have been observed, the remaining 120 European species being peculiar to Spain, Italy, Greece, Russia, or Lapland. Of the German species, 94 occur in Belgium, but only 65 in England—though we possess one species, *Erebia Cassiope*, which does not occur in Belgium.

All the British butterflies occur in England, but little more than half (only 33) are found in Scotland, and scarcely more in Ireland.

Twenty-five species may be considered as generally distributed and common; but it should not be understood that these are everywhere to be met with, but simply that their geographical range is not limited, and that where they find suitable localities we may expect to meet with them from Norfolk to Killarney, and from the Isle of Wight to Caithness. Some frequent gardens, some meadows, some heaths, some woods, and some hedgerows and lanes.

Twenty-five other species, which all occur in the south-east of England, thin out as we advance northwards and westwards; only five of them occurring in Scotland, and only fourteen in Ireland.

Three species, two of which are common in the mountainous parts of Scotland, do not occur at all in the south of England.

Seven species are local to particular limited districts in the Midland Counties or the south of England.

Three species of rare occurrence in this country must be looked upon as stragglers from the Continent; one of them, *Vanessa Antiopa*, has occurred in the south-west of Scotland and at Dunbar.

Two other species, which formerly occurred in restricted English localities, now appear to be extinct there.

It has been observed by Dr. Speyer, who has devoted considerable time to the subject of the geographical distribution of the butterflies of Germany, that the number of species there decreases from east to west and from south to north; but the latter circumstance is partly owing to the configuration of the country, the Alps being particularly rich in butterflies.

That butterflies are not regularly distributed according to latitude, is evinced by the simple fact, that in Lapland, which is situated considerably further north than the Shetland Isles, they enumerate seventy-seven species, whereas Scotland only boasts of thirty-three. Silesia, on the eastern side of Germany, but in the same latitude as Belgium, has 124 species, about one-third more than Belgium, which only numbers ninety-four. Berlin, though further north than Paris, has more species of butterflies, the numbers being ninety-six and eighty-nine; and the neighbourhood of Berlin is, as any traveller can testify, very monotonous, and not particularly likely to yield any extra variety of forms.

In the same way we find that there are fewer species of butterflies in the western counties of England than in the eastern counties.

Dr. Speyer has suggested that the more continental character of the climate of Eastern Germany, the greater cold in winter, and greater heat in summer, was favourable to the development of butterfly-life, and tended therefore to account for the greater number of species there. This theory is certainly corroborated by the distribution of the species with us: their maximum is reached in those portions of England which have the most continental climate.

In respect of the species peculiar to moors and mountains, it is needful to bear in mind that it is not latitude that effects their distribution, but the position of mountain chains of sufficient elevation. Thus the London entomologist travels north to obtain species which an entomologist at Brussels would seek in the south; and even in Ireland an entomologist would need to go southwards to obtain species in Kerry, which an Edinburgh entomologist would seek in the Highlands. Though *Cœnonympha Davus* is unknown in Southern England, simply because we have no boggy mosses there, yet in Bavaria we meet with mosses similar to Chat Moss near Manchester, and there this insect is again abundant.

From a comparison of the species which occur in Ireland with those found in Scotland, it appears that all the twenty-five, generally common species, occur in Scotland, though three, *Argynnis Silene* and *Euphrosyne*, and *Thymele Alveolus*, have not yet been detected in Ireland; of the more southern forms, fourteen occur in Ireland, but only five in Scotland; on the other hand, one of the mountain species common in Scotland, *Erebia Blandina*, has not yet been found in Ireland; and one straggler, *Vanessa Antiopa*, has occurred in Scotland, but not in Ireland.

In short, six species occur in Scotland but not in Ireland; on the other hand, eleven in Ireland, but not in Scotland.

Of the twenty-five more southern species, one, *Vanessa Io*, attains the latitude of Edinburgh on the eastern side of our island, and occurs right across the country, having been found at Falkirk and Renfrew. Of the remaining twenty-four, seven stop short at Darlington, nine at York, and eight at Peterborough;—that is, these are, speaking roundly, their northern limits on the eastern side of the island; several of them travel further north on our western shores; thus *Colias Edusa*, which is unknown at Newcastle-on-Tyne, has appeared in Dumfriesshire, in Ayrshire, and in the Isle of Arran. *Argynnis Paphia*, which has not actually occurred quite as far north as Darlington, has been observed at Arrochar, and even in the neighbourhood of Rannoch.

Of the three moor and mountain species, *Cœnonympha Davus* is that which is found furthest south in England; it occurs near Uttoxeter, and is plentiful on the mosses between Warrington and Manchester; it also occurs at Thorne Moor in Yorkshire, and on wet bogs near Newcastle and near Carlisle. In Scotland it is very general on mosses and hill-tops. In Ireland it occurs in the counties of Cork and Kerry.

Erebia Blandina is first found at Wharfdale in Yorkshire, then at Colne, Kendal, and at Castle Eden Dene. In Arran, Argyleshire, Dumbartonshire, Perthshire, &c., it is widely distributed.

Erebia Cassiope is not found further south than Langdale Pikes and Styehead Tarn; it always occurs at a great elevation, from 1500 to 2000 feet above the level of the sea. In Scotland it occurs on Ben Lomond and on some of the Perthshire mountains. In Ireland it occurs at Galway and Donegal.

With regard to those species which are excessively local with us, the circumstances which cause their restriction to such very confined localities are at present unknown to us. They are not so restricted on the continent; *Papilio Machaon* and *Polyommatus Acis* are universally distributed in Germany; and with the exception of *Pamphila Actæon*, all our other local species are very generally distributed in Germany, though not occurring in every district.

Of the three stragglers in this country, *Pieris Daplidice*, *Argynnis Lathonia*, and *Vanessa Antiopa*, the two former seem confined to the southern counties of England, not ranging north of Peterborough; but *Vanessa Antiopa* is most plentiful between the Humber and the Tyne, and has more than once been observed in Scotland.

Of the two species which may be considered extinct with us, one, *Chrysophanus Dispar*, used to be abundant at Whittlesea Mere; but since that was drained, causing cornfields to wave where reeds had formerly held undisputed sway, the insect has disappeared. Similar fen districts still exist in Norfolk and Suffolk; but though the insect has been sought there in its most likely haunts, no recent captures are known.

With reference to the distribution throughout the globe of our sixty-five British butterflies, it may be remarked that fifty-nine occur in Asia, twenty-seven are found south of the Mediterranean, several cross the Atlantic, and one, *Cynthia Cardui*, is cosmopolitan.

Dr. Dickie, in his able paper on the Distribution of the Aberdeenshire Plants, divided, according to Mr. Watson's suggestion, our British Flora into the British, English, Germanic, Atlantic, Scottish and Highland types.

It may readily be conceded that the twenty-five generally common butterflies correspond to the British type of plants; the twenty-five more southern butterflies to the English type; but unless we refer the three moor and mountain species to the Highland type, we cannot follow the same system of classification further.

We have not a single butterfly peculiar to our west coast, nor a single one peculiar to the north; the circumpolar species which occur in Lapland do not reach us; neither have we any one species peculiar to the eastern coast of England. We simply trace, as we advance northwards, a gradual decrease in the number of species: every one of our British butterflies is abundant in the South of Germany.

Account of the Fish-rain at Aberdare in Glamorganshire. By the Rev. W. S. Symonds.

The evidence of the fall of fish on this occasion was very conclusive. A specimen of the fish was exhibited, and was found to be the *Gasterosteus leiurus*, Cuv.

On Drift Pebbles found in the Stomach of a Cow. By the Rev. W. S. Symonds.

The author exhibited thirty pebbles, one of them weighing three-quarters of a pound, found in the stomach of a cow lately killed at Barton-under-Needwood, Burton-on-Trent. The pebbles belong to the Northern drift of geologists, which abundantly overlies the New Red Sandstone of the district; and they are remarkably glazed and polished by the action of the cow's stomach. The weight of the pebbles is five pounds, and the animal appeared perfectly healthy and fat when killed by Mr. Goodman, butcher, of Barton-under-Needwood, to whom reference may be made.

Note on Falco Islandicus *and* F. Grœnlandicus. *By* James Taylor, *Medical Student, Aberdeen.*

Falco Grœnlandicus and *F. Islandicus* have been confounded by some writers; they are considered distinct by Mr. Hancock, and Mr. Taylor's observations confirm this view; *F. Gyr-falco Norvegicus* is an allied species. *F. Islandicus* is largest, viz. 23½ inches; in the adult of both sexes the predominating colour is brownish-grey spotted. *F. Grœnlandicus* is intermediate in size, viz. 22 inches; in the adult of both sexes the predominating colour is bluish brown, and greyish white beneath. *F. Gyr-falco Norvegicus*, an allied species, is smaller than either.

The author has seen all the three species, and the *F. Grœnlandicus* more than 200 miles over the south-west ice in Greenland. When on the cliffs which they frequent, this last species rests in a leaning position, as if on the point of commencing flight. The *F. Grœnlandicus* is rather indiscriminate in choice of food, capturing ptarmigan, puffins, gulls, and various species of sea birds.

On the Employment of the Electrical Eel, Gymnotus Electricus, *as a Medical Shock-Machine by the Natives of Surinam. By* Prof. George Wilson.

This paper was an appendix to a communication "On the Electric Fishes as the earliest Electrical Machines employed by mankind," brought before the British Association at its meeting in Dublin in 1857.

In addition to the facts concerning the employment of the Gymnotus as a remedial electric agent mentioned in that communication, the author has ascertained two others of some interest. Humboldt, in his 'Personal Narrative,' refers to a Dutch surgeon named Van der Lott, as having published in Holland a work in the last century 'On the Therapeutic Use of the living Gymnotus.' Through the kindness of Baron J. L. de Geer, of the University of Utrecht, the author has learned that Van der Lott's work consisted simply of a letter dated Rio Essequibo, 7th June, 1761, and published by one of its members in the 'Transactions of the Haarlem Society of Arts for 1762,' where it may be consulted. The point of chief interest contained in it is the statement that the Dutch colonists, with the sanction of some at least of the medical men, were in the habit of treating, and frequently with success, lameness, paralysis, and headache, as occurring among their negro slaves.

The other point referred to by the author is the fact recently ascertained by him, that the use of the Gymnotus continues in Surinam at the present day. Robert Kirke, Esq., of Burntisland near Edinburgh, who resided in that colony for some twenty years, informs him that he was in the habit, as other owners of estates also were, and still are, of keeping two or more living electrical eels in a tank, for the use of the negroes and Indians, who have great faith in the power of their shock to cure rheumatic and paralytic affections. The negroes combine the administration of the Gymnotus-shocks, which they know how to vary in strength, with the application to the ailing part of the fat of the boa constrictor; but they invariably ascribe the cure, if such is attained, to the shocks. An uncle of Mr. Kirke's, Dr. James Balfour, who practised medicine in the end of the last and beginning of the present century in Berbice and Demerara, was in the regular habit of employing the eels to give shocks, which he said he had found of great use in the cure of rheumatism.

It thus appears that the native Indians, the imported negroes, the Dutch and English colonists of the districts where the Gymnotus is found, have one or other employed it as a therapeutic electric machine from time immemorial down to the present day.

The author mentioned in conclusion, that Mr. Kirke had kindly engaged to procure next summer a pair of living Gymnoti for him. He trusted they would arrive safely in Edinburgh, where they would be accessible to all scientific men.

Physiology.

Case of Lactation in an Unimpregnated Bitch. *By* John Adamson, *M.D.*

A greyhound bitch, four years old, has never had pups. She is a usual occupant of a hearth-rug along with a cat, with which she has always been on very friendly terms.

This cat had kittens, and one being spared, it was soon allowed to join the family group on the hearth-rug, where in a short time it rivalled, and almost supplanted its mother in the affection of the greyhound. Before long it was observed to make an occasional attempt to reach the greyhound's teats, the process evidently at first discomposing the bitch, although she generally submitted to it. After a time this occurred regularly, and led to an examination of the teats, which were found to be slightly enlarged, reddened, and to contain a few drops of milk.

In a few weeks, during which the sucking continued regularly, the glands were noticed to have become much larger, and the amount of the secretion was so great that one gentle squeeze easily caused the emission of six or eight drops from any of the enlarged glands; it was apparent, indeed, that the kitten was deriving a great part of its nourishment from the bitch.

About this time the old cat, which had long ceased to notice the kitten, had another litter in a stable in which the greyhound was shut up at night; and the first intimation of it was given by the appearance of the bitch on her way to the house with a young kitten in her mouth: she exhibited every appearance of maternal affection to it, and the remainder of the litter being speedily destroyed, there ensued a curious struggle between the cat and the dog for its possession. In this the greyhound succeeded; and the cat was only replaced in enjoyment of her maternal rights, by placing the kitten in a box with an entrance hole large enough only to admit the real parent.

The greyhound whined piteously, and was disconsolate for a whole night and day, but in the end again took to her former foster pup, and to the present time she nurses it, even although it has grown into nearly a full-sized cat.

The milk-glands of the bitch were the size of large figs, and the posterior four only are excited, viz. those taken by the kitten. The other and anterior glands are not affected, but only indicated, as were the others before the sucking, by the position of the small teat.

On the Repair of Tendons after their Subcutaneous Division. *By* BERNARD E. BRODHURST, *F.R.C.S.*

Attention was drawn to this subject by the author four years ago, when he displayed the ordinary mode of healing after subcutaneous division of tendons. In the present communication, the experiments above referred to are detailed, and the question is examined whether, "after subcutaneous section of tendons for the cure of deformity, the necessary extension for the removal of distortion can be made without a cicatrix being apparent in the tendon which has been divided." And, further, whether "the new material between the divided ends of the tendon subsequently contracts or elongates."

From various experiments which the author has made, he deduces the following conclusions:—

1st. When a tendon has been divided subcutaneously, if its divided ends are approximated and the limb is kept at rest, reunion will take place, and probably without new material or cicatrix being apparent.

2nd. The new material which is formed between the divided ends of the tendon may be drawn out to any required length; having been extended, it remains a permanent structure, and it may afterwards be recognized as a new deposit.

3rd. There is a tendency, during some months, and whilst consolidation is taking place, for this new tissue to contract.

4th. Should extension have been commenced too early, or should it have been carried on too rapidly, paralysis will result; and if a limb be used immediately after the division of a tendon, reunion may be prevented. Also, if it be used before the tendon has gained sufficient consistence, so great elongation of the new tissue may result, as to cause weakness of the limb; but, on the other hand, should the extension be insufficient, distortion will recur.

On the Beat of the Snail's Heart. *By* MICHAEL FOSTER, *M.D.*

In the heart of the common snail (*Helix hortensis*), the force of each beat is in direct proportion to the distension of the cavities during the preceding diastole.

Any part of the heart separated from the rest will beat rythmically, provided too much injury be not inflicted upon it by the act of division, the likelihood of which increases rapidly with the smallness of the piece operated upon.

If the heart be divided in anyway, the resulting pieces will each contract rythmically, not necessarily synchronously with each other, but each having the whole of its tissue occupied in the production of every beat.

Hence the beat cannot be the result of any localized mechanism, but is probably the peculiar property of the general cardiac tissue.

A Second Physiological Attempt to unravel some of the Perplexities of the Berkeleyan Hypothesis. *By* RICHARD FOWLER, *M.D., F.R.S. &c.*

I should not venture to ask for the attention of the Section to, apparently, so psychological a subject as the Berkeleyan hypothesis, if I did not think to satisfy others, as I have satisfied myself, that some of its obscurities could be cleared by a reference to physiological facts. For instance, a portrait painter searches to get, not only the fixed features, but the adjusting capabilities by which they express the thoughts of the mind; when he is satisfied he has succeeded in this, he copies it on his canvas: here then Mr. Locke is right; the conception has passed through the senses to the intellect. The creations of the poetical painter, on the contrary, pass *from* the intellectual senses.

Now Berkeley has said, "That a conception has no existence but while it is perceived;" yet in both the instances cited, the conception remained fixed and permanent in its existence for years, though no one is present to perceive it.

The sublime "Cathedral of York" must have been a conception in the mind of the architect, and have existed for ages a reality, though for long intervals not perceived by others. The "Great Eastern," the conception of Brunel, as other conceptions, the materialized inventions, remain enduring existences when not perceived by any one.

I may here remark on the difference between discovery and invention.

Discovery comes to the intellect through the senses, by facts suggesting search, as in the case of the planet Neptune. Now the bridge to connect mind with what is external to the mind, will be found, I think, in the pre-established affinities of the forces with which phenomena are composed, and the mind which perceives them. Such affinities constitute the pre-established harmony suggested by Leibnitz.

All chemical affinities are of this kind; all sensational, all intellectual, all associations of ideas, the affinities of force for each other, as magnetism for iron (see Ampère).

What is the bridge which affords communication from mind to mind for thousands of miles, but the Electro-magnetic Telegraph, the two forces of electricity and magnetism passed from the galvanic trough to the vibrating needles at the ends of the conducting wires?

The thoughts that constitute this subject are so numerous and evanescent, so far away from the ordinary occupations of men, that I have great doubts of being able to arrange them without being both tedious and obscure.

In Berkeley's time, matter was supposed to consist of atoms, with an impenetrable nucleus surrounded by attractive and repulsive forces; he probably saw that all the phenomena perceived by the mind were affected by these forces, without contact with the supposed impenetrable nuclei. He was aware, too, that all our knowledge consists, not of objective, but of subjective impressions, and therefore that we had no certainty that any objects external to the mind had existence, but that all we saw, heard, or touched, were merely modes of mind, and that the phenomena had no existence when not perceived.

The permanent existence of phenomena is, I think, proved by the instances to which I have referred in the former part of this paper—the portrait, for example, and all inventions of art, real creations of the mind.

If this be so, the severance or gulph between matter and mind will be found to be bridged over by affinities analogous to the chemical, as the oxygen of the atmosphere has for the carbon of the blood, or by forces modified by their coils. The force light, for example, carries the species, or resemblance of the face through a camera obscura to the sensitive surface on which it is fixed, and remains permanent, both in time and space, though not seen in its passage by the eyes of others. Thoughts embodied in words pass by the forced motion from one concave disc to another at a distance of many feet (as at the Polytechnic, and the whispering gallery at St. Paul's Cathedral).

The air is the medium through which such motion passes, and when modified by different musical instruments, results in songs and operas, and all the varied phenomena which can be produced by sound.

The vitality of sap in trees is so modified by the graft coil through which it passes, as to result in varieties of fruit corresponding with the graft. The motion by which a ship moves is modified by the adjustment of the sails, the rudder, paddles, and screw. Now the law of these forces requires investigation, and is clearly (as Turgot and Dugald Stewart asserted) independent of the mind, and external to it. May it then not be asserted, as affirmed, that the forces are the bridges by which the mind passes to and from the phenomena which it perceives?

I am afraid that I may not have been sufficiently explicit as to the means by which the severance between matter and mind may be bridged over by an affinity, or a force; but I consider that, in addition to the seven physical forces, of which Mr. Grove has so ingeniously proved the correlations, mind and vitality are equally forces, as I have attempted to prove in former papers, and that these—mind and vitality—have such correlations with the physical forces as to form the communication which bridges over the apparent severance between mind and matter.

On the Comparative Action of Hydrocyanic Acid on Albumen and Caseine. By A. Gages, *M.R.I.A.*

There is scarcely any problem in Physiological Chemistry of more importance than to find satisfactory means of distinguishing the various albuminoid bodies from one another. The processes hitherto employed are very unsatisfactory when the substances are in solution, and are almost wholly valueless when the substances are in a coagulated state or in solution in acids. The great similarity between the reactions of all albuminoid bodies, their almost identity of per-centage composition, led to the belief that they were but modifications of one another. The action of deutoxide of hydrogen upon fibrine shows us, however, that there is a positive molecular difference between fibrine and albumen and caseine. The author has found that this opinion is fully borne out by the peculiar reaction of hydrocyanic acid with albumen. If pure caseine be put into a solution of hydrocyanic acid, it remains unaltered in colour and other properties. If hydrocyanic acid is added to milk, it coagulates it in the same manner as other acids do; and if the quantity of acid be large and the mixture be kept in a well-stoppered bottle, the caseine remains unaltered for a long period of time, and even after three years hydrocyanic acid may be detected. If, on the other hand, the white of an egg is introduced into a concentrated solution of hydrocyanic acid, it first coagulates, and after some time dissolves, the solution gradually darkens until it becomes a blackish muddy-looking mass; nevertheless, as in the former case, hydrocyanic acid may yet be detected even after three years.

On Reproduction in Gasteropoda, and on some curious Effects of Endosmosis. By Robert Garner, *F.L.S.*

In the shell-covered, water-breathing, creeping mollusks, with one or two exceptions, reproduction is simple enough, there being male and female individuals *without* or *with* sexual congress. In a chiton or limpet we have the former arrangement, the testes in the male and the ovaries in the female opening in the chiton between the branchial processes, and in the limpet near the rectum. This disposition was pointed out by the author a quarter of a century back, though one of the latest and best general treatises on comparative anatomy asserts that these openings have never been detected. In fact, the disposition in the limpet was known to Cuvier. The common Paludina is a species where the sexual congress takes place. We only refer to this animal (during the last few years introduced, with the American weed, into districts where it was before wanting), that we may mention the very curious spermatozoa to be found in the male, and occasionally, of course, in the female. They have indeed been figured by Leydig, and perhaps by others, but I believe imperfectly. As seen by a high power, they present a truly wonderful and beautiful appearance. They may be from the eighteenth to the twentieth of a line in length, and are not strictly locomotive, but are moored by six or eight fine filaments at the tail, the rest of the thread-like body bending or extending in various ways; having also, at the same time, a wavy appearance, seemingly due to the spiral rotation of its length. When water is applied to them, the posterior part of the body gradually swells into a globular form, and by degrees absorbs the linear part; this still continues to show motion; finally, we have nothing but a globular sac with the finer caudal filaments sticking from its side, and this at length bursts. Mixed with these are other extremely fine filaments, so fine that they are liable to be overlooked with even a high power; they appear to be corkscrew-like towards one extremity, and have a less active but progressive movement; though with water they double themselves up with a loop, and move extremely rapidly. That these are a stage of the former there is little doubt, as there is more or less resemblance in some of them. They may perhaps originate from the pencil of filaments to be seen in the larger bodies.

But reproduction in the other Gasteropoda, particularly in the shell-less and water-breathing species, and the air-breathing (with one or two exceptions), is accomplished by very curious organs. Perhaps they are as complicated in the different species of *Helix* and *Bulimus* as in any, and we shall describe them in the former; hoping that we shall advance a step in the physiology, and make certain the difficult anatomy. Each individual of these animals is considered to be *androgynous* or hermaphrodite, or to have the organs of both sexes; yet to become fertile, the concurrence of two individuals is generally required.

The gland situated at the extremity of the spiral shell was naturally considered by Cuvier to be the ovary; after examination with the microscope, no one now can doubt it to be the testis; but is it solely such, or does it consist of ovary and testis combined? This is the present prevalent opinion. But to us it appears a testis, and nothing more. At one time we believed it to be a double organ; but at last, in the *Limax*, when we thought the numerous nucleated bodies must be ova *par excellence*, we found that, on the addition of water and watching them narrowly, they gave origin to spermatozoa, and also showed us the way in which these last are developed, somewhat different from the same thing in the Vertebrata. We see in the testis both large and very small cells, the larger containing several of these last. The small cells occasionally burst within the larger ones, and each gives exit to a spermatozoon, which was spirally coiled in it; and in the large cell we finally see collected a double bundle of spermatozoa: as often the mother-cell bursts by endosmosis, and the smaller ones escape, resembling ova or egg-yolks; but if we add water, and watch, we shall see each one swell, and the contained spermatozoon unrol and make its escape. In *Arion* each compound cell gives origin to a much greater number of these spermatozoa. They are sometimes seen rolled up into a close coil with the head, or a portion of the anterior part unrolled. With water or a thin fluid, the mature object stops in its movements, and twists upon itself into a battle-door shape. The vas deferens is ciliated and generally stuffed with spermatozoa, often exceedingly vivid in their motion, so that they coil themselves into rapidly rotating cables. This tongue-shaped part is called the glue-organ, and sometimes the testis, by Cuvier; no doubt it is in part an organ furnishing glue or albumen, but we believe that it also comprehends, together with its granular prolongation, the ovary; above, it contains diaphanous globules and grains of albumen, but below, these have every appearance of egg-yolks. The ovary of Sepia consists in great part of the same gluey matter. I think its true structure has never been discovered; it is best seen in the *Limax*, late in the year, when less distended; by teazing and extension, it may be developed so as to be seen to consist of a wide duct and alternately pinnate ramified prolongations from the same. The inferior prolongation is of the same structure. At the base of this ovary ends the vas deferens in a wide contorted canal, called the matrix by Cuvier, or rather in a groove or false duct running along its side to near its lower extremity; whence it is continued as a perfect canal, which goes to the intromittent organ. Into the matrix also the ovary opens above. The spermatozoa must pass into what is considered the penis by this canal. It is lined by a mucous membrane, which is easily separated, and the cells of which look at first like ova, but are smaller. I have rarely in the *Helix*, if ever, found traces of spermatozoa in this duct, but the anatomy seems to prove the nature of the parts. The so-called male organ is situated in the *Helix* close to the general opening, and of course is everted in coitu. It then carries a remarkable spermatheca, or horny strap or ribbon, with the edges involuted, and the spermatozoa may be found in a tuft at its extremity; and the penis itself is inserted in coitu into the common duct of the so-called vesicle or "poche copulative," and its blind appendage. The spermatheca is formed in the lash-like prolongation of the penis, and along it may be seen moving spermatozoa. The blind appendage seems to be distended sometimes with a thin fluid, perhaps acting by endosmosis on the spermatozoa, and the vesicle is a reservoir from which the spermatozoa, or at least the vivifying fluid containing them, is discharged into the matrix, where it meets the egg-germs, easily obtaining ingress from above and the side. In many species of Mollusks I have found the contents of the vesicle as described. The extremity of the spermatheca may be found at first in the blind appendage; then it is broken up and conveyed into the bladder, but often the principal portion of it (three or four inches) will be found hanging out of the animals, after the reciprocal approach. The ova then are impregnated in the matrix of each animal by the influence of its fellow; they receive a strong coating of albumen from the ovary, and investing membranes or shelly coats from the matrix itself, where they are afterwards found fully developed in its folds.

In a strong muscular sac, evertile also, exists, as is well known, an organ of excitation in the shape of a calcareous dart or spear. This is formed from the secretion of the two fimbriated organs, near the base of the sac: I have found that their milky product effervesces with a little acid; besides, they only exist where the dart is employed. I shall not describe this curious instrument, as it has been often noticed; but may mention that *Helix virgata* has two sacs and two curved lances, like miniature elephants' tusks. In *Carocolla lapicida* the secreting organs are only two long simple cæca. Cuvier does not figure, in the *Helix pomatia*, the long appendage of the vesicle, so remarkable in *Helix aspersa*. In *Helix nemoralis* the neck of the vesicle is very long, its appendage originating higher up, and floating at the end, and all these parts very dark with pigment. *Clausilia* has a short appendage and no dart: the slugs have neither.

It is curious that the hollow conical base of the dart, marked by its ridges, from twelve to eighteen, is often found after the sexual approach in the neck of the vesicle; I suppose accidentally. Another curious fact is that the dart itself, though it may be seen sticking from the flank of the animal, or fallen to the ground, yet generally is found in the interior of the animal, amongst the fimbriæ, by the side of the matrix, or often where the vas deferens joins the ovary. Why this is, seems doubtful; my theory is that the recoil of the animal into its shell when struck may cause the dart to enter so deeply, and that it has no other function than that of a stimulus.

It may be seen, then, that each snail reciprocally impregnates and is impregnated. There is a transference of spermatozoa, possibly of ova, though I think not in *Helix*, though so in *Limnæa*. In the sexual congress the male organ is found, finally, with its opening to that of the vesicle and its appendage, but at first closely applied to that of the matrix, with the spermatheca a little inserted. Does it supply the matrix first, and then the vesicle or pouch of reserve? or does (as is the case in some annelides for instance) the spermatic fluid of one individual occasionally impregnate itself by the aid of the second? I think not; for what would then be the use of the intervening duct? Once I found the penis half-exserted and lying in its own vaginal cavity. This I consider accidental, and no proof of self-fertilization. I have given the anatomy correctly; perhaps some one cleverer at an enigma may give a better solution with respect to the physiology.

We have noticed the spermatozoa of *Helix* and *Neritina* (some species of which appear to be hermaphrodite) to put on the forms of ordinary cells by endosmosis. In the vesicle and testis of *Helix* are often found immense numbers of extremely active animalcules, having much the appearance of columnar cells. If we add water, they quickly become tadpole-like in form, are still more active, and finally globular and motionless; the endosmosed spermatozoa cannot be distinguished from the moving cells or animalcules, if they are such, and both may resolve into globules; but we only mention this as a curious correspondence. How the spermatozoa are finally disposed of, we are not aware; we suppose by solution. They are in *Helix* from the twentieth to the thirtieth of an inch in length, the vitellus about the $\frac{1}{1500}$th, so that the theory of their entering it can scarcely be held in this instance.

Limnæa stagnalis has similar organs, but no appendage to the penis, and consequently no spermatheca. It is remarkable that here the vas deferens divides and goes both to the matrix, through a tortuous ciliated duct, into which the ovary also opens above, and likewise to a second canal, analogous to the false duct of the *Helix*, but here not communicating with the matrix, but communicating, as well as the tortuous ciliated duct, with the ovary above; and it would appear that both ova and spermatozoa may be conveyed by the second canal through the reservoir at the bottom, through the interventional duct, and so to the intromittent organ or penis and ovipositor (as it would be in addition) in this case, whilst through the first series ova and spermatozoa might both descend into the matrix, and so the animal be fertile *per seipsum*. I have found the spermatozoa in the first tract more frequently than in the corresponding one in *Helix*. I have no doubt on this head. I believe that in *Limnæa* ova may also be transferred by the same route, unless sperm- or tissue-cells have been mistaken for them. In *Limnæa* there are two distant openings for the male and female organs. I have noticed that in the sexual approach one set of organs are often solely employed, so that there would appear to be a probability of barrenness in one. Often also three individuals are concerned in the act, and one might escape fertilization; and again, there is no doubt that the animal, raised from the fry and kept distinct, may be fertile: in the supply of spermatozoa through the double duct to both series there may be an instance of the fecundity so general in nature. I should add that there is a distinct gland here, opening into the lower portion of the contorted canal, which appears to have the office of furnishing albumen to the ova, secreted first under the form of lucid particles of regular form, too large to be called molecules; of which, however, there is an abundance in these organs, some with very active movements, which I suppose we must call monads; others more minute, darker, and less active, and which must rank as colour particles, or active molecules.

The transit of the interventional duct in *Limnæa* through the muscles of the side of the animal was considered by Cuvier to be an approach to that disposition, where the penis is widely separated from the other organs, and connected only by a groove in the flank, as in *Bullæa* or *Aplysia*. The *Doris* or *Eolis* presents a simpler type, and *Hyalæa* or *Cleodora* one simpler still. All of these I have examined, but need not dwell upon.

The Specific, Chemical and Microscopical Phenomena of Gouty Inflammation. By A. B. Garrod, *M.D., F.R.S. &c.*

Dr. Garrod remarked that many and discordant views were held concerning the nature of gouty inflammation, and such diversity of opinion arose from the fact, that, up to the present time, no characteristic structural change had ever been demonstrated to accompany it; the object of his communication was to supply that deficiency, and prove that special chemical and microscopical phenomena invariably attend true gouty inflammation. After alluding very shortly to the views held by the ancients, and within the last century by Murray Forbes, and Wollaston, and by Cullen and his followers, and to the difficulties which each had to contend with in applying their hypotheses to the explanation of the various symptoms of the disease, he proceeded to speak of his discovery of the constant presence of uric acid in the blood in gout, and his subsequent researches in the nature of that disease. From these he drew the three following conclusions:—

1st. In *health*, the blood contains minute traces of urate of soda and urea, and probably of all the principles destined for excretion; but the quantities are so small, that the most careful and refined analysis is required to demonstrate their presence.

2nd. In *gout*, the blood is invariably rich in urate of soda, and uric acid can be readily crystallized from it.

3rd. In by far the greater number of diseases the blood is free from an abnormal quantity of uric acid, but in certain cases of albuminuria, lead poisoning and other affections, its presence can be demonstrated, and still no gouty inflammation ensue; lastly, in many gouty subjects the same condition exists in the intervals of the paroxysms.

From these conclusions Dr. Garrod considered it evident that something more than the mere presence of urate of soda in the blood was required to produce gouty inflammation, and his next object was to ascertain its nature.

For this purpose a careful examination of the joints which had suffered was required, and within the last few years many opportunities had fallen to his lot; the subjects of these examinations were divided into four classes:—

First. Subjects of chronic gout with extensive chalk-stones.

Second. Subjects of gout with no appreciable deformity, and no visible deposits of chalk-stones, except one or more specks on the external ear.

Third. Subjects of gout in whom no trace of chalky matter was externally visible, and in one case only eight attacks of the disease had occurred.

Fourth. Subjects in whom only a single joint (the ball of a great toe) had been affected with gouty inflammation, or in whom some joint had only been once slightly inflamed.

These examinations proved beyond the possibility of doubt, that in the very slightest forms of the disease, as well as the most severe, a structural change invariably occurs, and that this change, when once produced, remained, if not permanently, at least for a very lengthened time. After detailing the microscopical and chemical characters of the deposit producing this change, Dr. Garrod finished his communication by stating that he considered the facts which had been brought forward warranted him to conclude that—

"Specific, chemical and microscopical phenomena *invariably* accompany gouty inflammation, and these consist in the deposition of urate of soda in a crystalline form within the cartilages and ligamentous structures of the joints; and that such deposition is altogether pathognomonic, never being found in any disease other than true gout." And again, that "such deposition is probably the cause rather than the effect of the inflammatory action."

Lastly, the author pointed out the great importance of ascertaining the true nature of the disease as a means of conducing to its rational and successful treatment.

[The paper was illustrated by careful drawings and chromolithographs.]

Necessity of a Reform in Nerve-Physiology. By G. H. Lewes.

The author began by describing the inextricable confusion at present existing in the writings of physiologists owing to the want of a fixed nomenclature. No two writers agreed as to the precise meaning of sensibility, sensation, &c. The consequence was that experiments were constantly misinterpreted, one writer declaring he found no trace of sensibility, where another writer found abundant traces.

There was also very general confusion in the use of the terms Property and Function. These terms it is indispensable to have precise in meaning; we ought no more to confound them, than to confound oxidation with affinity. The *property* of a nerve is that which belongs to it as a nerve, and depends on its physical *structure*. The *function* of a nerve is the *use* to which that property may be applied, and depends on the anatomical connexions—the organic relations established between the nerve and other parts of the body. The property is therefore constant, the functions variable. The nerve which is connected with a gland is similar in structure and in property to the nerve connected with the skin; but the functions are different, because the connexions are different.

Having once settled this precise distinction, we are lighted by it to an important principle, namely, that *identity of structure everywhere implies identity of properties, diversity of structure diversity of properties*. Iron is always iron, and always retains its properties as iron, whether it be fashioned into chains, nails, anvils, windlasses, or cannon. The *uses* to which the iron may be applied are various.

In like manner nerve-fibre is always nerve-fibre, and has always the same *properties*, though not the same *functions* or uses. It is an error to suppose that there are two distinct kinds of nerve, sensory and motory; one class being, it is said, only competent to convey stimuli *from* a centre, and the other only *to* a centre; one being said to convey motory stimuli, and only these; the other to convey sensitive stimuli, and only these. It sounds ridiculous to say that iron is capable of being rendered magnetic at one part of a crank but not at another; yet a similar assertion is made respecting nerve-fibre without misgiving.

Physiologists are unanimous in ascribing sensibility to the ganglionic substance of the encephalon, or some portion of it; but they are also unanimous in denying this property to every *other* ganglionic mass in spite of identity of structure. No physiologist has bethought him of the necessity he is under—if he would retain his belief in the brain as the *exclusive* seat of sensibility—of proving that the ganglionic substance of the brain is essentially *different* from the ganglionic substance of the medulla oblongata and spinal cord; because with difference of structure would come difference of property. And such an attempt would be vain. There is *no* difference as regards fundamental characters; the fibres, granules, cells, and connective tissue found in the one are found in the other: nothing is found in the one that is not in the other: they are identical. Our conclusion, therefore, must be that they are identical in property. If sensibility be the property of any ganglionic mass, it must be the property of all. Numberless experiments have shown the author that *every* ganglionic centre in a vertebrate or invertebrate animal is the seat of sensibility. Physiologists declare the phenomena to be due to reflex action, not to sensibility; but this the author considered to be only one among the many *équivoques* which arise in the absence of a scientific nomenclature.

Whatever the peculiar force developed in the *centres* may be, it assuredly is not the same as that developed in the *nerves*. Nerve-fibre has one property, the nerve-cell another. It is proposed to call the one *neurility*, and the other *sensibility*. By neurility is meant the property of the living nerve-fibre, which excites *sensation* in a centre, *contraction* in a muscle, and *secretion* in a gland. By sensibility is meant the property of the living nerve-cell, as contractility is the property of the muscular fibre.

By recognizing the simple fact that all nerve-centres whatever, no matter how various their functions, have one common property, such as sensibility, we shall be able to find our way through many obscurities of nervous physiology, and shall understand how the spinal cord of vertebrata, or separate ganglia of invertebrata, can separately manifest sensation and volition—as experiment proves—we shall understand why an animal like the Amphioxus, which has *no* brain at all, is capable of sensation and volition, though not of what we call *thinking*; and, finally, we shall understand why all animals, in spite of the great diversities in their nervous systems, have one fundamental character in common, and that is sensibility.

The author concluded by proposing that the British Association should appoint a committee of physiologists to draw up a Report, and to lay the basis of a new nomenclature. From the illumination of many minds a reform might issue, and a new era be inaugurated.

A Demonstration of the Muscular Sense. By G. H. Lewes.

Physiologists are generally agreed as to the existence of a special class of sensations arising from the exercise of the muscles and regulating their adjustments; but there are still disputes as to whether these have their origin in the muscles themselves, or in the skin. The following experiments were made by the author to determine whether the stretchings and foldings of the skin were or were not the source of these sensations.

A frog was completely skinned, with the exception of a small patch around the anus, and another patch over the eyes and nose. On all the parts from which the skin had been removed, there was absolute *insensibility to all external stimuli*: pricking, pinching, cutting, cauterizing, and burning were all unable to elicit the slightest trace of sensibility. A leg was cut off bit by bit, without the frog's once moving; but in the two spots which still retained their skin, sensibility was easily excited. A touch or a prick made the frog hop away, draw up its leg, or defend itself.

If this frog were placed on its back, it immediately turned round again, and settled its legs comfortably. If the hind legs were pulled abruptly down, they were quickly drawn up again; but if they were pulled gently down, they remained where placed—until a few minutes had produced a feeling of fatigue in the stretched muscles, and then the leg was withdrawn. Had not the frog *felt* this position uncomfortable, there would have been no reason for altering it. The proof of this was seen by *varying* the position: in proportion as the position was *unusual*, it was maintained for a shorter period. To these evidences of muscular sensibility may be added the leaping, and the complicated actions of self-defence when irritated, none of which could be effected without nice muscular adjustment.

The frog, therefore, which has been rendered totally insensible to *external* impressions, by removal of its skin, is still seen to manifest all those phenomena usually attributed to the muscular sense. A question arises, whether these phenomena are due to any feelings originating in the muscles, or are solely due to the will of the animal, that is to say, whether the brain may not be the source of the phenomena? To settle this, the author repeated the experiments on frogs without their brains, and without their skins. The phenomena were precisely as before.

Experiment having thus proved that the sensations assigned to the muscular sense have not their source in the skin nor in the brain, the only alternative is to conclude that their source is the muscles themselves, the action of which awakens the sensibility of the spinal cord, either through the anterior, or through the posterior root of the spinal nerves—in the author's belief, it is through the anterior root.

On the supposed Distinction between Sensory and Motory Nerves. By G. H. Lewes.

The author began by declaring the anatomical discovery of Sir Charles Bell to be firmly fixed; but the physiological inference deduced from it to be questionable. The fact that the anterior roots supplied the nerves to the muscles, and the posterior roots supplied those to the surfaces, established an anatomical difference between muscle-nerves and skin-nerves, but did not establish the physiological inference that muscle-nerves were only motory, and skin-nerves only sensory. The author held that both nerves were sensory *and* motory; but that owing to their anatomical connexions, the anterior nerves were more largely implicated in motions, and the posterior in sensations.

The supposed distinction between the two classes, if essential, and not merely one of degree, must be either a distinction in property or in function. That there was no essential distinction in *property*, seemed proved by their identity of *structure*. This the author showed in detail. Then, as to the distinction in *function*, it was easy to see this could only be one of degree, since function is determined by anatomical connexions; and these are much more alike than is generally supposed.

There are nerves which on being irritated excite *muscular contractions*; and these nerves we can follow into the very substance of the muscles, where they end. There are other nerves which on being irritated excite *sensations*; and these we can follow into the substance of the sensitive surfaces, where they end. Finally, there are nerves which excite both contractions and sensations, and these we can follow into muscles and the skin. This is Bell's immortal discovery. This is the anatomical distribution of the nerves. Yet it does not force assent to the proposition that one of these nerves is sensory and the other motory, because in the foregoing we have only described *one half* of the anatomical distribution of the nerves. Let the *whole* description be given as modern investigations enable us to give it, and there will no longer be any doubt that, as regards the *central* connexions, the two nerves *agree* very closely, consequently they must *agree in function*; and as regards their *peripheral* connexions, the two nerves differ, consequently they must *differ in functions.*

By an oversight, which will one day excite surprise, physiologists, while insisting on the *peripheral* differences in the two nerves, have, without one exception, disregarded the important fact of the *central* agreements. No one has investigated the minute anatomy of the spinal cord without being aware that both anterior and posterior nerves are in direct connexion with its grey matter; yet the conclusion has been overlooked that if both are in direct connexion, both must play upon and excite the sensibility of this grey matter. Were the properties of the two nerves different, it would be intelligible that their effects on the centre should differ; but as their properties are similar, their effects on the centre must be similar.

Logic forces the conclusion, that, in as far as the *central* connexions of the two nerves are similar, their functions are similar; but inasmuch as their *peripheral* connexions differ, their functions will differ. The function of moving a muscle is assigned to those nerves which are connected with muscles; the function of transmitting impressions of touch, temperature, &c., is assigned to the nerves connected with the surfaces.

Thus the posterior nerves are sensory because they are related to a sentient centre. They are *also* motory, because they are related, though in but a trifling degree, to the muscular fibres distributed through the skin; and these they excite to contractions. The anterior nerves are motory because they are related to muscles. They are *also* sensory, because, like the other nerves, they are related to a sentient centre. In other words, both nerves are at once sensory and motory, although the motory function of the posterior nerves is necessarily slight, because the muscles of the skin are insignificant.

If we ask what *form* of sensibility the anterior nerves are likely to excite, the answer cannot be long in forthcoming—it must be muscular sensibility. That we have a Muscular Sense, by means of which we adjust the manifold niceties of contraction required in our movements, we must all acknowledge; and it has been shown in a previous communication, that this muscular sense is derived through the muscles, and not through the skin; and further, that it exists after all sensibility to *external* stimuli has vanished. This muscular sensibility must be derived either through the posterior or the anterior nerves; but is *not* derived through the posterior nerves, as Arnold, Brown-Séquard, and the author have proved by the decisive experiment of dividing the posterior roots. When these roots are divided, the muscular sensibility is affected, but not *destroyed*; and if *any* sensibility exist, it must be due to the stimulus of the anterior nerves. Brown-Séquard divided *all* the sensory roots of the four extremities of a frog, and found that not only did this frog execute its ordinary muscular adjustments, but when its nose was irritated with acid, it rubbed away the acid with its fore-leg.

The conclusion is that our muscular sensations are derived through the muscle-nerves—there being no *other* channel for them. The argument against the sensory function of the anterior nerves is this: if we divide the posterior root and irritate the end which is attached to the spinal cord, the animal gives unequivocal signs of sensation; but if in the same way we divide and irritate the *anterior* root, the animal gives *no* sign whatever of sensation. The ends of the nerves which are no longer in connexion with the cord, are irritated, and in the one case *no* motion is produced, in the other it is.

Those who demand that an irritation of the anterior root should be followed by the *same* signs of sensation as follow irritation of the posterior root, demand a *kind* of evidence which *cannot*, in the nature of things, be manifested. The sensibility excited by the muscle-nerves cannot be the same as that excited by the skin-nerves, any more than the sensibility excited by the optic nerve can be the same as that by the auditory nerve. No one doubts that the optic nerve is sensory; yet it cannot respond to stimuli of odours, sounds, heat, cold, or touch; whatever stimulates it, will only produce the one special form of sensibility we name Light. Cut it, pinch it, burn it—and no pain is produced, only the sensation of a flash of light. Now, on the supposition that the anterior nerves minister to muscular sensibility, it is obvious that they can only manifest signs of this *special* sense, and not signs of *other* senses. There are certain stimuli which awaken muscular sensations; but whatever awakens them, they will always react in one and the same way. Let us suppose that irritation of the anterior root by pricking, or by galvanism, *does* awaken this muscular sensibility; by what sign could it betray itself? The irritation produces no *pain*—no more than irritating the optic or auditory nerve produces pain. It can only produce a sensation, such as precedes or accompanies adjustment of the muscles; but the muscles which were in direct connexion with this irritated root are now—by the division of the root—removed from its influence, and *cannot* therefore be adjusted; and the other muscles *are* adjusted. What sign, then, could be manifested? Evidently none at all. Consequently the experiment, so far from being decisive, does not touch the real question.

The author then passed to the motory function of the posterior nerves, which, he considered, must necessarily be slight, because function depends on anatomical connexion, and unless a nerve be distributed to *moving organs*, we cannot expect it to produce *motions*. Now the posterior nerves are *never* distributed to the muscles. Schiff has proved that they pass through and along the muscles, and send filaments to the envelopes of muscles, but never terminate in the muscular substance itself. This explains why irritation of a posterior nerve excites no contraction in the muscles if the anterior root be divided.

But seated in the substance of the skin to which these posterior nerves are distributed, there are certain contractile elements—minute muscular fibres—which supply the hair follicles. It is *these* which are moved by the posterior nerves. Slight as the function of moving such insignificant muscles may be, it is enough to destroy the established doctrine respecting the exclusively sensorial function of the posterior nerves.

To resume in a few words the conclusions of this paper:—If the supposed *essential* distinction between the two nerves issuing from the anterior and posterior columns of the spinal cord exist at all, it must be either a distinction of *property*, inherent in the nerves, or of *function*, resulting from anatomical distribution. But there is no distinction of property; both nerves having identical structure must have identical properties; and experiment has shown that both nerves are capable of conducting in *both* directions. Nor is there any essential distinction of function; both nerves agree in being distributed to the spinal cord, which makes them both sensory in function; and although the two nerves differ in their peripheral distributions, the one going to muscles, which makes it pre-eminently a motory nerve, and the other to the skin, where the muscles are very insignificant, which makes it only motory in a small degree, yet these variations in degree are not such as would imply the *essential* distinction universally attributed to the two nerves. Both nerves are sensory and both are motory; yet inasmuch as the skin-nerves, from the fact of their distribution, are the channels of more *intense* and more *various* sensations than the muscle-nerves can be, these skin-nerves may continue to be styled sensory, by way of convenience; and inasmuch as the muscle-nerves are the channels of more *energetic* and more *various* movements than the skin-nerve can be, they may properly continue to be styled motory nerves. But it is important to recognize that the verbal distinction between the two nerves represents no *essential* distinction. The posterior nerves are skin-nerves, and are the channels for the sensations and contractions of the skin; the anterior nerves are muscle-nerves, and are the channels for the sensations and contractions of the muscles: this is the distinction between them.

On the Homologies of the Coats of Tunicata, *with remarks on the Physiology of the Pallial Sinus System of* Brachiopoda. *By* J. D. MACDONALD.

An Experimental Inquiry into the Action of Alcohol on the Nervous System. By W. MARCET, *M.D., F.R.S., Assistant Physician to the Westminster Hospital, &c.*

The object of the communication is to determine whether the action of alcohol is transmitted to the nervous centres by means of the circulation, or whether this action depends on the contact of the fluid with the nerves of the stomach.

The author divides into three series the experiments he has undertaken on the subject in question.

In the first series he investigated the action of alcohol on the healthy animal, choosing the frog on one hand, and the dog on the other. In the second, he cut through the nerves supplying the parts in contact with or immersed in alcohol, leaving the circulation undisturbed; in which experiments frogs only were used. In the third series the circulation of the parts immersed in alcohol was arrested, and the action of the poison on the nervous centres was noted. Frogs and dogs were submitted to these last experiments.

The specific gravity of the alcohol used was 833. The posterior extremities of the frogs were immersed in alcohol of this strength up to the commissure of the thighs. Alcohol, diluted with an equal bulk of water, or less in some experiments, was injected into the stomach of dogs by means of a syringe. In order to prevent the circulation of the stomach from taking place, the author tied the thoracic aorta of dogs by means of a peculiar kind of aneurism needle invented by Mr. Trant of Dublin.

The following were the results obtained from these investigations.

Results from the first series of experiments.

1st. When the hind legs of a frog are immersed into alcohol, the sensation and respiration of the animal cease in from ten to thirteen minutes.

2nd. The posterior extremities of the frog, which are in contact with alcohol, become insensible and powerless sooner than the other parts of the body.

3rd. A shock occasionally takes place shortly after the immersion, which consists of the complete cessation of the sensibility and mobility of the animal, although respiration continues; and on irritating the eyeball, the eyelids appear to remain sensible.

4th. The shock, occurring shortly after the immersion, may continue until the respiration of the frog stops, there being little or no return of spontaneous or excited muscular action.

5th. The shock, observed occasionally when frogs are experimented upon, may disappear shortly after its occurrence and return again afterwards.

The inquiry into the action of alcohol upon a healthy dog showed—

6th. That alcohol acts first on the brain, next on the spinal cord, and lastly on the sympathetic system,—a result fully confirmed by the experiments on frogs.

Results from the second series of experiments.

1st. When the crural nerves of a frog are cut through; the animal, having its posterior extremities immersed in alcohol, will preserve its sensation and respiration for from fifteen to twenty-three minutes, and consequently for a few minutes longer than when a healthy frog is submitted to experiment.

2nd. The contact of alcohol with the hind legs of a frog whose crural nerves have been cut, does not give rise to a shock.

Considering together the results from the first and second series of experiments, it is concluded that the *principal* channel through which alcohol acts on the nervous centres is *the circulation*; but also that the poison exerts a *slight* influence on the nervous centres exclusively through *the nerves*.

Results from the third series of experiments.

1st. If the abdominal aorta of a frog be tied and its body included within a ligature, leaving the crural nerves quite free, the animal, whose hind legs have been immersed in alcohol, preserves its sensation and respiration for from four to eighteen hours, while another frog, thus operated on, but not immersed in alcohol, continues feeling and breathing for upwards of twenty-three hours.

2nd. When the hind legs of a frog, operated on as mentioned above, are placed in alcohol, a shock may occur.

3rd. After having placed a ligature on the thoracic aorta of a dog, the injection of any quantity of alcohol into the animal's stomach produces no sign of intoxication; while in the case of a healthy dog, as little as one ounce of alcohol (diluted with an equal bulk of water) is sufficient to bring on rapidly symptoms of poisoning.

4th. Although after the ligature of the thoracic aorta of dogs the injection of alcohol into the animal's stomach produces no sign of alcoholic intoxication, still a dog thus experimented upon dies sooner than another, who, having undergone the same operation, is not made to take any alcohol.

These results, considered in connexion with those obtained from the preceding experiments, prove beyond doubt that alcohol acts on the nervous centres *principally* by means of *absorption*, and consequently through the *circulation*, but also that this substance exerts a *slight* influence on the nervous centres by its contact with the *extremities of the nerves*, this action hastening the cessation of life without producing any other effect.

Moreover, the author concludes from his experiments, that whenever alcohol produces a shock, it is due to a peculiar action of the poison transmitted to the nervous centres exclusively through the nerves.

On the Organs of the Senses, and on the Mental Perceptive Faculties connected with them. By W. E. C. Nourse, *F.R.C.S., Fellow of the Royal Medical and Chirurgical Society.*

The following are the general conclusions arrived at in this paper.

1. The organs of the senses, so various in their structure, situations, and functions, nevertheless present the most exact analogies with one another, both in structure and function.

2. Respecting structure, they each consist of two essential parts:—1st, a *mechanical*

apparatus, calculated for the purpose of isolating and defining external impressions, and of transmitting them; 2ndly, a *conductor of nerve*, whose peripheral expansion communicates with the mechanical apparatus, the other extremity terminating in the brain, or being in direct communication with it.

3. Respecting function, they are all destined to convey impressions of the properties of matter from the outer material world to the mind; each impression being received by the mechanical apparatus, and transmitted to the nervous conductor, which conveys it on to the brain.

4. The reception and communication of an impression by the mechanical apparatus is capable of the clearest demonstration in all its details; its further transmission by the nervous conductor is ascertained, but the mode is not understood; and all physical trace of it absolutely ceases where the nervous conductor terminates. At this point it is materially and outwardly lost, but is instantly recognized inwardly and mentally.

5. The mind has a separate power or faculty of receiving each of the elementary impressions presented to it by the outward organs of the senses. Each impression pertains exclusively to one sense only; and with each sense is connected corresponding mental faculties for the perception of them.

6. The sense of sight is connected with two faculties; one for perceiving impressions of *colour*, and one for the *degree of light*.

7. The sense of hearing is connected with faculties for noting the *tune* and the *quality* of sounds.

8. The sense of touch or feeling is connected with faculties for the perception of *weight* or *resistance*, and *temperature*.

9. The sense of *taste* is connected with a mental faculty for receiving its peculiar impressions; and the sense of smell with another in like manner.

10. All further impressions of the properties of matter are deduced by inference from these primary ones, and are not directly perceived.

On the Genetic Cycle in Organic Nature. *By* Dr. Ogilvie.

Parental derivation is now generally allowed as the sole origin of organic beings, and the subject of discussion among physiologists is no longer the admissibility of spontaneous generation, but the nature of the derivation, in different cases, from a single parent or a pair. The former mode of origin, by what has been termed "gemmation," or the "budding process," plays a very conspicuous part in the propagation of many of the lower species, while in others the two seem to graduate into each other. In their usual manifestation they are distinct enough, in a functional as well as in a structural point of view. The evanescent vitality of the sexual elements, singly, strikingly contrasts with the enduring capacity for development, characteristic of gemmæ, and the structure of true ova is sufficiently peculiar to mark them off from all other reproductive bodies; but in drawing any conclusion in this matter, we must also keep in view the observations which have been made of the occasional incipient development of unimpregnated ova—of the full evolution without impregnation of bodies resembling ova, and in some cases undistinguishable from them, as in *Aphis* and *Daphnia*—and particularly of the impregnation of some germs; while others from the same ovary, destined for the evolution of young of a different sex, are developed without fecundation, as Siebold and others have shown to be the case in bees and some other insects. These observations lead to the conclusion that ova are essentially of the same nature with gemmæ—only modified and limited in their capacity of development, for certain special ends—rather than that there is any absolute diversity between them.

In their ordinary manifestation, however, the two modes of reproduction are clearly distinct; and when they concur in the same species, the immediate progeny is generally different, their succession giving rise to the singular phenomena known as "alternation of generations." All cases of alternation are not, however, to be regarded as precisely parallel; and it is the object of the present paper to point out certain differences, dependent on the period of the life-history of a species, in which the process of gemmation is interpolated. Three stages may be distinguished in the life-history—the Protomorphic, or that prior to the first appearance of the organization most characteristic of the species—the Orthomorphic, or that marked by such typical organization—and the Gamomorphic, or that of the development of the reproductive organs. In any one of these stages we may have a process of gemmation interpolated. The results contrast, especially as it occurs in the first and last. As examples of the first, may be mentioned the Trematode and Cystic Entozoa in the animal kingdom, and the Mosses among plants; in all of which certain provisional forms are interposed between the ovum and the embryonic rudiment of the typical form. The Polypifera and Cestoidea among animals, on the other hand, and the Ferns among vegetables, furnish illustrations of alternation dependent on gemmation in the Gamomorphic stage, and arising from the reproductive organs acquiring the characters of detached and often highly organized structures, comparable to independent animals or plants. The hood-eyed Medusæ become in this way much more conspicuous organisms than the polype-stock, whose organs they really are. The Cestoidea are remarkable as presenting instances of a double alternation, from a process of gemmation occurring both in the Cystic or Protomorphic, and in the Tænioid or Gamomorphic stages.

The succession of forms among the Aphides appear referable rather to an early phase of the typical or Orthomorphic stage. Another remarkable feature of this case is the extent to which the pullulation of gemmæ of the same general character is carried—amounting frequently to nine or ten in succession. A like continued pullulation to a less extent may take place in either of the other stages, but it is most common in the Orthomorphic, and generally occurs in connexion with cohesion of the gemmæ, so as to give rise to those arborescent forms characteristic of the Polyzoa and Polypifera among animals, and of the whole vegetable kingdom.

A parallelism may be indicated between the phenomena of alternation and certain points in the embryogeny of the higher animals, and in the maturation of the reproductive organs. The formation of double monsters in the higher animals, the normal twin embryo of the Polyzoa, the variable number of Tænia-heads budded off by the Cystic Entozoa, and the phenomena of development among the Echinodermata, present us with indications of a gradual transition from the implantation of the embryo on the germ-mass of the ordinary ovum, to cases of well-marked alternation. The reproductive process, on the other hand, in the Polyzoa and Hydraform Polypes, in the Salpæ and in some Annelides, and the phenomena of impregnation in the Coniferæ among vegetables, furnish illustrations of a similar transition from the development of the normal reproductive organs, to the formation of conspicuous sexual zooids. In proof of distinctions founded on the *complexity* of the structures themselves not being of essential importance, reference may be made to the males of the Rotifera and Cirrhipedes, which, though animals with an individuality entirely distinct even from the ovum, are much more defective in organization than some of the sexual zooids now referred to, such as the hood-eyed Medusæ. The like accidental nature of the character of *isolation*, or independent vitality, may be inferred from the power of dismemberment possessed by some of the lower forms of organization, and from the persistence of a certain proper life in particular regions, even of those higher in the scale, as for instance, in the hairs and teeth of mammalia.

[The paper was illustrated by tabular views of the relations referred to.]

On the Method of Production of Sound by a Species of Notonecta. *By* Peter Redfern, *M.D. Lond.*

During the summer months of the year 1858, the author kept a number of small beetles in an aquarium with other objects. Amongst the beetles was a small Notonecta with exquisitely marked wing-cases. Not many days had elapsed when a peculiar chirping noise was heard now and then during the day, but much more frequently and continuously in the evening between nine and twelve o'clock. The sound resembled the imperfect pronûnciation of the letters *chew* three times in succession. It was heard repeatedly at short intervals for a while, and then, after a much longer pause than before, it was reproduced. At first it gave rise to the idea that a cricket had got into the house, though the sound was not like that produced by this insect. It was then noticed that the sound was most distinct in the neighbourhood of the aquarium, and that during its production one particular Notonecta was invariably engaged in the same occupation, viz. that of rubbing its fore-legs busily upon each other. The sound was never heard except when this act was being performed, and at the time it was heard no other of the creatures was even seen engaged in any particular manner nor placed in any special or constant position, though they were repeatedly and carefully watched. When examined with a pocket lens, and with a low power of the compound microscope, the part of the Notonecta's legs, of which it made use at the time of the production of the sound, was seen to be covered with stiff hairs or other projections of its external covering. Further examination of the part was delayed until other specimens could be secured, and during this time the original was unfortunately lost. Yet notwithstanding that the examination was less complete than might have been wished, the opportunities of examining the action of the animal at the time it produced the sound were so numerous, that there can be no doubt that the noise was caused by rubbing the fore-legs together, a method which seems either very rare amongst insects, or to have been but rarely observed and recorded.

On the Admixture of Nervous and Muscular Fibres in the Nerves of the Hirudo Medicinalis *and other Leeches. By* PETER REDFERN, *M.D. Lond., F.R.C.S.L.*

The author stated that very remarkable movements take place in the nerves of leeches after removal from the body, and that though they had been known to him since October 1847, when they were shown to him by Dr. Mandl, he believed that their existence is yet but little known. These movements have been demonstrated in the class of Histology in the University, and King's College, Aberdeen, for the past twelve years; the author informed Professor Goodsir of them in 1848, and showed them to Professor Paget's class at St. Bartholomew's Hospital in 1855. Mayer states that Hannover first observed them. Remak ascribed them to the contraction of muscular fibres within the nerve-sheath. Leuckart and Will have observed similar phenomena in the nerves of insects and Naiads.

The author pointed out that the best method of showing these movements is to remove one or more of the ganglia and their branches from the gangliated cord of the leech, to dissect away the sheath very carefully with needles, so as to leave the ganglia and nerves perfectly bare and free from all adhering muscular fibres. On waiting for a short time, slow but very decided oscillatory movements of some of the nerve-trunks may be observed in almost every instance examined. These movements take place quite indifferently in the large cords connecting the ganglia, and in their gangliated and non-gangliated branches. The action of water elevates the neurilemma of the nerves into vesicles, and shows the cause of the oscillatory movements. The attention should be directed to the concave side of any of the branches of nerve which are curled, or to both sides of nerves which are oscillating; and one or more muscular fibres of the ordinary characters of the fibres of the leech may be seen in every moving nerve at one period or other of the action of the water. When the movement is compared with that which may be seen in ordinary muscular fibres of the leech when stimulated by the contact of water, the character of the two movements is found to be identical. The author has not seen movements continue for more than a few minutes in the dissected muscular fibres, but he has repeatedly watched them for half an hour, several times for 50 minutes, and once for 70 minutes, in the nerves of the leech. He gave no opinion on the purposes served by this peculiar mixture of nervous and muscular elements, where nervous elements alone were formerly supposed to exist, but expressed a desire that the members of the Association would make the occurrence more generally known, that, by the labours of a number of physiologists engaged in the examination of different animals, it may be determined to what extent in the animal kingdom these so-called elementary tissues are mingled, with the view of arriving at some plausible conjecture as to the nature of the end gained by such an arrangement.

On the Structure of the Otoliths of the Cod (Gadus Morrhua). *By* PETER REDFERN, *M.D.*

From examination of the otoliths of the cod, haddock, flounder, salmon, and various species of trout, it appears that their structure is similar, and therefore the otoliths of the cod may be taken as representing the rest. They require to be examined by making sections of them in three different directions in the usual manner: some of the sections should be left of considerable thickness, others should be made as thin as possible, that the general arrangement, as well as the minute structure, may be examined.

The great otolith of the cod is an elongated flattened body, convex on one side, concave on the other. In the natural position, the concave surface looks upwards, backwards, and a little outwards; the anterior extremity is wider than the posterior, and one edge straighter than the other; but both are curved, and the whole body is twisted, the concavity of the under surface being produced by a groove which runs obliquely along. The convex surface has a longitudinal ridge running along it, dividing it into two unequal parts, the smaller being bounded by the straighter edge. This otolith, when in position, appears to form one wall of an irregularly rounded osseous cavity, from the interior of which sonorous vibrations may be reflected upon the otolith and thus affect the nerves. Both surfaces, the concave one especially, present transversely directed flutings which run outwards to the edges of the body. The flutings are visible on the transverse, longitudinal, and horizontal sections. The appearances presented by such sections were shown by coloured drawings.

The longitudinal and transverse sections present dark lines passing completely through the otolith from one surface to the other, and dividing it into separate masses or lobes. Of these lines there are four, running longitudinally and seen on the transverse section; and nineteen running transversely, and seen on the longitudinal section, so that, on the supposition that the division is equal in all the parts of the otolith, it consists of seventy-six separate lobes. The lobes which are near the middle of the body have all their diameters nearly equal, but those near the margins are elongated with their long axis stretching out to the margin.

Each lobe is made up of complete concentric laminæ near its middle, and of partial parallel laminæ near its surface; the partial laminæ of one system being interrupted where they are met by those of another system in the position of the lines before named.

The laminæ are marked with striæ, which run perpendicularly to their surfaces, and indicate their formation of prisms or very thick-walled tubes.

In speaking of the development of otoliths and similar hard parts of animals, the author referred to the theories of formation of tissues from cells, and by a process of molecular coalescence, stating his belief that, by repeated examinations made at different periods, the mode of formation of these tissues might be clearly determined.

Miscellaneous.

On the Disguises of Nature. *By* Andrew Murray, *Edinburgh.*

This paper was devoted to an inquiry into the laws by which the external forms of natural objects are regulated—as elucidated by an examination of the resemblances which certain animals and plants bear to other objects, animate and inanimate. These the author termed the disguises of nature, and separated them into those which imitated inanimate objects and those which took the appearance of other creatures. The chief part of the paper was occupied in discussing the former; and as regards them, the author suggested the principle of attraction as the direction in which a general law might be looked for. In examining the resemblances to inanimate objects, he brought together a great many curious and interesting examples of both; but it was chiefly with the imitations of inanimate objects that he occupied himself in his attempts to discover a law explanatory of the facts.

[This paper has been published *in extenso* in the Edinburgh New Philosophical Journal.]

GEOGRAPHY AND ETHNOLOGY.

On the Arabic-speaking Population of the World. *By* A. Ameuney (a Syrian).

The Arabic has 29 letters, which, with the combinations and the vowels, make about 36. Seven of these letters are, to a foreigner, exceedingly difficult to pronounce. The Arabic being an original language, it has, of course, the masculine and the feminine genders—and the dual. It has more. It has a personal pronoun, and a pronoun attached to the verb, like the Latin *amo*. It has feminine in the singular and in the plural to the verbs; so, if two people happen to be in the next room, and they were talking, you would know whether they be ladies or gentlemen, or whether one be a lady or a gentleman; or whether the speaker be a lady or a gentleman, or whether the party spoken to be a lady or a gentleman. Not so in any other language —partly only in Greek. We have singular, dual, and plural—plural below No. 10, and above No. 10; we have a plural of plurals, and a collective plural, and its plural. Let us see what we can do with these roots. Take the word *love*. We want to use it in English: we add r, and make lover, or ing, and make loving; or prefix be, and make beloved; but you have to say the place of love, the cause of love, and the course of love (they say it never runs smooth)! You have kill, and a knife, and butcher, and slaughter-house! We have nine letters, say a, b, c, and, by adding or prefixing one or more of these to the original, we make a word—one for the place, one for the instrument, one for the cause, and one for the passion. Take the word love, again, as a verb. You can only say might, should, or would, love; cause to love, command to love, ask to be loved, to be passionately in love, and to fall in love. But with us, we have thirteen other letters, and, by prefixing or adding one or more to the original word, we change the meaning. We only change the accent of the noun, and make it a verb. You have something like it—a présent, and to presént, a récord, and to recórd. There are 65,000 words in the English Dictionary. We have 150,000 in the Arabic, and, when the derivatives are added, the language becomes really formidable. There are a few languages in which there are more than four or five names for an object. You have sword, scimitar, and cutlass, but we have 150 names for this instrument of death. We have 160 for an old woman, 120 for the hyena, and I should feel ashamed to tell you how many for the lion, the camel, and the horse. It is all very well for a poet, who wants to rhyme his verses, to have many words at his command, but the language becomes very formidable for the scholar and the foreigner. The Arabs did not differ from other primitive nations. They traded with, warred against, hated, and loved their neighbours. Their wars were mostly with the Persians and the Abyssinians, for their poems refer to these nations in particular. They had their national assemblies, as we have here now. There was one in particular like the British Association—that is, comparing small with great things. During the month of Moharem they ceased their wars, and they met at Ackos, where the great poets recited their poems, and arbitrators decided which was the first, second, and third best. The first was then inscribed in letters of gold, and hung up at the Kaaba. We have seven of these poems (Moallakât), and many other lesser ones. Few nations have ever produced their equal,—I speak not lightly of the poetry of other nations. It was my great desire to read Sir Walter Scott's poetry that urged me to learn the English language. I have read several of the best poets in English, French, Italian, and Latin, but all appear to me to write too much. An Arab poet says all he wishes to say in a few verses. I am sure all Arab poetry is burning with a strong passion. The wars of Arabs have ever been either for women or horses, and their poetry is full of expressions about them. The eyes, the lips, the breath, the neck, and skin of a woman have more names than I could tell you of. Terreack! breath of life; wine, coffee, water of life, and paradise. The Arabs in their native simplicity are frugal, can endure fatigue, hunger and thirst, but the Arab can never become rich, because he is so generous. From the days of Abraham to this day his great delight is to entertain strangers. They have no hotel charges. Brotherhood is one of their strong ties. One becomes a brother either by a present or service rendered. People who live in towns present—give to one of the chiefs, and he can travel amongst the tribes. Antar had made war on a tribe, defeated it, and was leading the people into captivity. A man called out to him, El Goman, Antar!—that is, The Covenant, Antar asked him, where and when he ever covenanted with him. "I was," said the man, "once at such a well watering my horse. You came and wanted to do the same, but your rope was too short." Bread and salt is another thing; the refuge another. Whether Christianity ever made any great progress among them we do not know. There are, however, many Christian tribes, especially in Hauran and Korak. But as soon as Mohammed appeared, the Arab mind took a different turn, and they became a conquering race. They, in fact, burst the bounds of their desert, and went out—the Koran in one hand and the sword in the other—either submission or death. After a little while came the tribute, or redemption. People redeemed themselves by paying an annual tax (very small), and they lived in peace. Then they extended to Syria, Mesopotamia, Egypt, Tripoli, to the borders of the Alantire, &c. The Arabs are like the Anglo-Saxons; they conquer, give their language, manners, and customs to the conquered nation, and in a short time they make them Arabs.

On the Country to the West of the Caspian Sea. By Baron DE BODE.

On the Geography of Southern Peru. By W. BOLLAERT.

On the Laws of Consanguinity and Descent of the Iroquois. By Dr. W. CAMPS.

On the Relation of the Domesticated Animals to Civilization. By J. CRAUFURD.

Mr. C. showed the great service rendered to mankind by domesticated animals, in furnishing them with food, labour, and also clothing, entering into a number of statistics. The total value imported of articles of clothing, the produce of domesticated animals, was, in 1857, 34,000,000*l.* In the same year we imported raw and manufactured silk to the value of 19,400,000*l.* Other imported commodities amounted to 5,334,300*l.* Of domestic animals and their produce we imported in all, in that year, to the value of 44,000,000*l.*—still a small sum compared with that furnished by our own cattle. He hence concluded that civilization is deeply indebted to the domestication of animals.

Two Axe-heads in the possession of Mr. P. O. Callaghan were exhibited by Mr. R. CULL.

Remarks on the Inhabitants of the Tarai, at the foot of the Himalayas. By JOSEPH BARNARD DAVIS, *F.S.A.*

After a description of the extensive country skirting the base of the southern slope of the Himalayas, to which the name *Tarai* is applied, which varies in its breadth, character, and elevation, and also greatly in its productions, but is uniformly the seat of a malaria of a pestilent nature, so as to render it very poisonous to Europeans, and even to the natives of the plains of India, reference was made to a number of tribes of people, the constant inhabitants of the Tarai, who dwell there with impunity. From the native name for malaria, *Awal,* these tribes have acquired the designation of "Awalian Tribes," equivalent to those who breathe the awal unscathed. They are in general uncivilized people, without letters, with only few and simple arts, having a fermented drink made from rice or millet, and some few of them distilled spirits. They practise a rude and simple agriculture; spin, weave, and dye; the latter being the domestic employments of the women. These they treat with confidence, kindness, and respect; and in all the family relations they are exemplary.

Notwithstanding the pestiferous emanations, the Awalian tribes occupy the very districts in which these are evolved; they erect their dwellings there, clear the forests, chiefly by fire, cultivate the open grounds and depasture their herds in them all the year round,—"they not only live in them, but *thrive* in them." The Bodòs and Dhimàls even allege that they could not endure the climate of the open plains below.

This singular property of resistance to pestilent emanations, a property enjoyed by many of the lower animals, is also a peculiarity of many of the tribes of India,—those called, for the sake of distinction, Turanian. The Kòls, the Bhìls, the Gònds are all fine and healthy races of men. The Negro tribes inhabiting the great river-districts about the Gulf of Benin enjoy the same immunity; whilst Europeans cannot at all withstand the atmospheric poison, as was proved in a most lamentable manner by the Niger Expedition of 1841. When negroes are transported across the Atlantic, this extraordinary property still adheres to them, proving that it does not arise from any external influence whatever, but is an essential inherent quality. In the Southern States of America the negroes are almost insusceptible of malarious diseases, marsh fevers, and that pestilence, the yellow fever. And a still further proof of this being an original property of the race is afforded by the fact, that, among the mixed breeds, every degree, even the smallest, of African blood tends to diminish the susceptibility to these diseases. It is a physiological attribute of these malaria-resisting races of men, their blood being possessed of some chemical property or some vital force which counteracts and overcomes the morbific cause, and which is not further explicable. That it is native, inherent, and also incommunicable, except through the blood, cannot be questioned; and that it indicates essential differences among human races, too subtle for the scalpel of the anatomist to reveal, and far too recondite for the zoologist to appreciate,—still congenital, demonstrable and ineffaceable,—is a matter well deserving the attention of anthropologists, especially as all the facts known afford no countenance to the assumption that these differences result from any secondary causes whatever. Negroes, so far from exhibiting any remarkable vigour of constitution, are always characterized, in all climates, by the prevalence of an *asthenic* type in their diseases; and the self-deluding presumed influence of vast lapse of time in developing resistance could in this case operate only in an opposite way, and that cumulatively and destructively, by impairing, debilitating, and deteriorating every succeeding generation more and more.

The paper was concluded by a description of the physical characters of the tribes inhabiting the Tarai, which was illustrated by a series of good coloured drawings, executed by a native artist, born in the great valley of Nepal.

On Meteorology, with reference to Travelling, and the Measurement of the Height of Mountains. By Admiral FitzRoy.

On the Ethnology and Hieroglyphics of the Caledonians. By Col. J. Forbes.

The author developed his views regarding what are called "Druid circles" in the following propositions:—1. Whether found singly or in groups, those circles not surrounding moot-hills or tumuli were erected for places of worship. They were also used as places for the administration of justice, and for the assembly of councils. 2. The number of stones in these fanes had reference to the number of individuals or families; and perhaps, in circles of greater proportions, were according to the number of towns or tribes to be represented in the councils, or benefited by the sacrifices at any particular cromlech. 3. Some of the cromlechs contained altars within the area. Occasionally the altars formed part of the enclosing circle, and in other cases the altars were outside of the circle. 4. In the same fane there were altars to more than one deity. 5. The origin of these fanes cannot be traced in any country; and nowhere, except in the Old Testament, does history or rational tradition fix the period when, or the people by whom, any one of these monuments was erected. 6. Open to the weather, incapable of being covered, and with long avenues of approach, the form of these fanes has apparently been devised in Eastern countries possessing a clear sky and warm climate. 7. These heathen fanes of Britain were afterwards used as places of Christian worship, but cattle continued to be sacrificed in them. 8. These fanes were also used as burying-grounds for Christians.

Description of Ghadamès. By Consul S. Freeman.

Notes on the Vitrified Forts on Noth and Dunnideer. *By* Sir A. L. Hay.

I have considered it worthy of the attention, and I hope of the inspection of some members of the Association, that the most remarkable of the vitrified forts peculiar to Scotland, and situated in this district, should be briefly described. The hill or mountains of Noth is situated in the district of Strathbogie in Aberdeenshire, upon the estate of his Grace the Duke of Richmond, rising to an elevation of about 1900 feet above the level of the sea. Noth is an elongated mass of mountain stretching from north-east to south-west. At its western extremity it is conical, and on its summit is constructed the fort, the ground having been apparently levelled for the purpose of its erection. The locality of the fort is at least three hundred feet above any part of the surrounding ground. The vitrified wall encloses a parallelogram rounded at its angles, of about one hundred yards in length by thirty-two in width; it is entered at the south-east angle by a causeway extending down the cone, and from which diverge several roads conducting to its base; this has evidently been the only entrance to this mountain strength. It is remarkable that the main road, and which appears to have been the principal line of access, is that leading to the wild district of Cabrach, the least populously inhabited country of the whole surrounding neighbourhood. The vitrified wall can be traced throughout its whole enceinte, with the exception of the above-mentioned entrance, and is more perfect than in any similar work in the kingdom: the portions of the wall which have been most perfectly vitrified are, of course, the most entire. I do not presume to solve the difficulty which naturally results from the various opinions as to the origin or construction of this extraordinary wall; but that it has been the work of human hands appears beyond doubt. The hypothesis of Pennant that it was the crater-rim of an exhausted volcano seems untenable. Williams, the author of the "Mineral Kingdom," considered it so. M'Culloch was of the same opinion. The late Sir George M'Kenzie held that the vitrifaction was produced by the effect of the ancient beacon-fires lighted on the approach of an enemy. Hugh Miller considered this very unsatisfactory, and added "that the unbroken continuity of the vitrified line militates against the signal-system theory." The causewayed entrance, the second and third lines of wall, the roads conducting from different parts of the country, all lead to a conclusion that this has been the stronghold of a district during barbarous ages. Allowing for the height lost by the accumulation of soil and rubbish at its base, it must have been at least eight feet high, to which is to be added the courses of dry masonry which had raised it to its original altitude, and the stones of which are now piled in innumerable quantities outside the vitrified remains. From the accumulation of soil it is now difficult to ascertain what has been the width of this extraordinary wall, but from all appearance it must have been from eighteen to twenty feet. In the centre of the fort is a well or tank. The appearance of the burnt or vitrified substances proves that an intense and long-continued heat must have been applied, and in many parts of the rampart the stone presents a glazed appearance. Lower down the conical part of the hill, and enclosing an area of twenty or thirty acres, is a line of wall to be traced by its remains, in parts of which the large blocks of stone continue in the positions they have originally occupied in the structure. This wall, with its distinctly-marked entrances and circular towers, surrounds what has been considered the vulnerable part of the hill, and is only discontinued at the southern face of the mountain, where the steep and inaccessible nature of the ground appears to have been considered a sufficient defence from attacks in that immediate direction. Another line of wall is perceptible at the base of the cone on which the fort stands; it embraces a very extensive area, but does not appear to have been a work of such strength or importance as that above described. The date of construction of these remarkable works, or the races by whom they were inhabited, is buried in mystery; neither the traditions of the country nor the page of history afford any information on the subject. That the population of a whole district, with their flocks and herds, had taken shelter therein in cases of hostile attack, appears probable, and there remain indications of habitations having been constructed inside of, and against the second line of wall above described. For the purposes of a mountain fortress the locality has been admirably selected, the only commanding height in its neighbourhood being at a distance of five or six miles—consequently too distant for offensive purposes previous to the discovery of gunpowder and the long range! It has been remarked by a former writer that "the vitrified enclosure on Noth is far more perfect than on any other of those works in Scotland, and is infinitely more remarkable." On a plain of some extent at the north and north-western base of the cone, in the direction of the Burn of Kirkney, are distinctly marked the tumuli said to contain the slain in the battle in which Lulach, the son of Lady Macbeth, lost his life in the year 1057. Upwards of one hundred of them are to be recognized; but whether the graves are those of the victims of many fights, whether this was the cemetery of the mountain-fort, or whether the above tradition is authentic, it is now impossible to determine. The place is called Mildewne—the grave of a thousand. The author of these notes opened five cairns on different parts of the field. The first, and, apparently from its magnitude, the most important, contained a stone coffin of very rude construction, but of such a description as to render doubt with regard to its original purpose out of the question. On removing the stones and earth to the depth of about three feet, a flag-stone of considerable size appeared: it was placed upright at the western extremity of the excavation, and, at the eastern, at a distance of about six feet, a similar one was discovered of lesser size, but standing exactly in the same position opposite. On the earth being removed from between these, a flat layer of stones became visible. These were placed so accurately, that at first it resembled one entire slab, but, on farther investigation, proved to be portions of flat stones placed very close together, and of a similar quality to those already described. In the four other cairns nothing whatever was discovered, from which it may fairly be conjectured that, in these barbarous times, the rights of sepulture were not attended with much ceremony or refinement, and that it was only in the case of a person of superior rank that even the rough and disjointed receptacle above described was provided. The view from the summit of the hill of Noth is very extensive. From it, with a clear atmosphere, may be distinctly seen the high grounds in nine counties—namely, Caithness, Sutherland, Ross, Inverness, Moray, Banff, Aberdeen, Kincardine, and Forfar. Near the village of Insch, in the district of Garioch, on the summit of a conical hill, with an elevation of about 600 feet, stands the ruined Castle of Dunnideer, erected on the site of a still more ancient vitrified fort of smaller size, but similar to that on Noth. It is not here necessary to enter into details of this specimen of the vitrified forts, which is neither so perfect nor so extensive as the one imperfectly described; but it forms some data as to their very remote antiquity, when it is stated that part of the vitrified materials are to be seen in the more modern building which became the residence of Gregory the Great, King of Scotland, who, according to Fordoun and other historians, died there in the year 893.

Description of Passes through the Rocky Mountains. By Dr. HECTOR.

On Gebel Haurân, its adjacent districts, and the Eastern Desert of Syria; with Remarks on their Geography and Geology. By JOHN HOGG, *M.A., F.R.S., F.L.S., F.R.G.S. &c., Honorary Foreign Secretary of the Royal Society of Literature*.*

In this communication the author gave a sketch of the recent descriptions of the *Lejah*, the *Haurân*, the *Gebel Haurân* range of mountains, and the district called *Ard El Bathanyeh*, the Batanæa of the Romans, portions of the former ancient kingdom of *Bashan*, as lately published by the Rev. J. L. Porter, and Mr. Cyril Graham; also an account of that part of the Syrian or Arabian Desert which is called *El Harrah*, and is situated to the east of *Gebel Haurân*, with a description of the elevated volcanic region on its northern border, named by the Arabs *E'Safah*, and in which are seen many high cone-like peaks, some of which are probably the remains of former craters. This account was taken from the descriptions given by Mr. C. Graham, the only modern European traveller who as yet is known to have reached those previously unexplored and long-forgotten regions.

The author exhibited a map of southern Syria, comprising a district from *Busrah*, about 36° 26′ 45″ to 37° 45′ nearly long. East from Greenwich, and from *Salkhad* and

* The entire paper (though without the Map) is published in the 'Edinburgh New Philosophical Journal,' vol. xi. (New Series) for April, 1860, pp. 173–192.

E'Deir, south of *Busrah*, about 32° 30′ to nearly the supposed centre of the Lake *Hijâneh* in the territory of Damascus, in 33° 20′ North. Lat. This he had drawn on a scale *eight times larger* than that of Mr. Graham's map, which had only been published a few days, in vol. xxix. of the 'Journal of the Royal Geographical Society.' He also coloured it, so as to point out the supposed boundaries of the different provinces under consideration, during the Biblical and Roman times, at least as far as could be determined with any accuracy.

It was further remarked that the most recent maps of Syria do not agree as to the exact positions of *Damascus* and *Busrah*; for, in Mr. Porter's first map, which he had the pleasure of communicating to the Royal Geographical Society in Nov. 1855, and published in the 26th volume of their 'Journal,' *Damascus* is placed in just about 36° 17′ 15″ E. Long. and in 33° 31′ 15″ nearly N. Lat., whilst *Busrah* is laid down in about 36° 26′ 35″ E. Long. and in 32° 32′ 20″ N. Lat.; whereas in the map by Henry Kiepert, engraven in Mr. Porter's 'Handbook of Syria,' published last year, the city of *Damascus* is laid down in 36° 16′ 40″ E. Long. and in 33° 31′ 40″ N. Lat.; but *Busrah* is placed in 36° 22′ 30″ E. Long. and in N. Lat. 32° 31′ 40″, thus giving a difference nearly as to *Damascus* of 35″ of Long. and 25″ of Lat.; and about a difference as to *Busrah* of 4′ 5″ of Long., and of 40″ of Lat.

The author then described the principal geographical features of the several regions represented in his large coloured map, adding, with some minuteness, accounts of their geology, as derived from the careful details chiefly afforded by Burckhardt, Porter, and Graham.

The geology of this entire region affords an example of many most important volcanic phenomena, such as are rarely to be seen within the same extent of country. The remains of distinct craters are apparent; whilst the whole region is more or less covered with igneous rocks, such as black trap, or basalt, either in the form of large boulders or outcroppings, and projecting masses. On some of the many conical hills, or *Tells* as they are termed in Arabic, larva and scoriæ, and pumice of various colours, are visible.

The author especially dwelt on the two more wonderful and extremely similar volcanic portions of that country, which may be termed *fields*, or *islands*, of black basalt, or of sterile igneous dark-coloured rock, namely, *El Lejah* and *E'Safah*. The former answers to the *Trachonitis* of the Romans, signifying a 'stony' district, and to *Argob* of Scripture; but the *ancient* appellation of the latter remains to this day unknown.

E'Safah, according to Mr. Graham, is even more horrible than the *Lejah*, for there, in many spots, good soil occurs.

Both districts are often intersected with caverns, and cracks, or *fissures*, of great depth and width; and the same traveller considers them to be "two of the most remarkable instances of a *volcanic* formation perhaps in existence."

So Mr. Porter, in like manner, describes the large *fissures* in the basalt in the *Lejah*, and writes, that its "physical features present the most singular phenomena he had ever witnessed, and to which there is not, so far as he knows, *a parallel* in the world, with the *exception* of the *Safah*."

The author, having examined some years ago the lava-beds and large volcanic deposits about Vesuvius, in the island of Ischia, and on the east and north sides of Etna, had never seen any chasms and *fissures* at all *parallel* to the phenomena, described as being so conspicuous in those of the *Lejah* and the *Safah*; and he showed that the *nearest parallels* are evidently several large lava-fields, and volcanic tracts, in Iceland, an island entirely of igneous origin, and more particularly so are the enormous clefts or *fissures*, termed in Icelandic, *gias*. In proof of this view, he described the two best known, and most extended, and deepest fissures, the *Hrafna-gia*, or 'Raven chasm,' and *All-mannagia*, or 'All-men's-chasm,' in the vicinity of Thingvalla.

Notice of the Karaïte *Jews. By* J. Hogg, *M.A., F.R.S., F.L.S., F.R.G.S. &c., Honorary Foreign Secretary of the Royal Society of Literature.*

The author brought this notice before ethnologists respecting the very ancient sect of Jews who call themselves *Karaïms* or *Karaërs*, the chief number of whom have for centuries inhabited, as they still do, several towns in the Crimea, in the hope that their history, the periods of their emigration from Palestine, of their subsequent wanderings and settlements, of their immigration from Asia into Europe, and the exact differences which they profess in their religious doctrine from the ordinary followers of the Jewish faith, might be more accurately investigated.

The distinguished Pallas was, he thought, the *first* to describe this remarkable people at the close of the last century; he found a great many of them living and carrying on trade at *Tchufut Kaleh*, i. e., 'the Jews' Fort', in the Crimea. That traveller stated that they reject the *Talmud*, and receive no other Jews into their community. They have a beautiful cemetery overshaded with fine trees, which they name the 'Valley of Jehoshaphat,' and from the numerous sepulchres there seen—nearly 4000, according to Démidoff—the population must have been large. The most ancient inscription on a tomb there is said to bear date 4727 of the year of the world, or 723 A.D., which, if correct, will show that they have resided in *Tchufut Kaleh* for more than eleven and a quarter centuries. They are stated to have been governed by their own magistrates.

Some have derived the word *Karaïm*, from *Kara*, a 'writing' (*scriptura*); and in addition to the chief difference in religion between the *Karaïtes* and the *Ordinary Jews*—which is the *rejection* of the *Talmud* by the former,—some variations in the Liturgy, in the mode of circumcision, in the rules respecting diet, and in the degrees of relationship which permit or forbid marriage,—constitute a very material distinction between these two great sections of the Jewish people. The *Karaïtes* have a synagogue at *Tchufut Kaleh* which has existed for many centuries, and in it are preserved some ancient *Thoras*, or MS. copies of the Pentateuch on vellum, and rolled in velvet cases.

A special commission is mentioned to have been appointed by the Russian Government some time ago to inquire into the condition, origin and settlement of the *Karaïtes*; and the following is part of the account confirmed by it, as taken from Baron von Haxthausen's work: "They assert their descent, pure and unmixed, from the tribe of *Judah*, which was led to *Babylon*:" that in the reign of Cyrus (about 536 B.C.) some of them returned to *Judea*; but that many, remaining after the destruction of Babylon, penetrated farther to the north, settled first in Armenia, and then spread by degrees to the Caucasus; passing over into the *Crimea*, they then resided there; and a few colonies at length, emigrating from thence, arrived in Poland.

They live in harmony with Christians, and regard *Christ* as a *Prophet* who proceeded from their own race, and whose disciples founded a *new* sect. Not having been in Judea in the time of Christ, they do not share the *animosity* usually entertained by Jews *against Christians*.

These Karaïtes differ from the *ordinary* Jews, of whom the inferior order is found in such numbers throughout Europe, not only in appearance, but also in character. The expression of their countenance is in general open and prepossessing. Both sexes are handsome, and have the general features of the Jews,—dark eyes, dark hair, &c. Great cleanliness of their persons distinguishes them mostly from their brethren, the Jews. They are polite, honest, and kind. They wear the Tartar dress, and are only known by their shaven faces, with narrow whiskers which reach to their chins. They have many Tartar customs and speak the Tartar language. As merchants they are enterprising, and are in great repute for their good faith and skill.

The author has failed to ascertain from his military friends, who were in the Crimea during the late war, the supposed number of *Karaïtes* still residing there, but he understood that it was much reduced by emigration and other causes.

Besides this population, some *Karaïtes* have been long settled in Poland, the Caucasus, Armenia, Jerusalem, and at Cairo; also at Constantinople. These last are stated by Dr. Frankl, in his recently published work, as amounting to about fifty families, with from 200 to 250 souls; and the same Jewish author mentions the same sect at Jerusalem, who "regard the *text* of the *Bible* with a sacred feeling as *alone* containing the *law*, and are therefore called *Karaërs*, i. e. *sticklers* for the *text*, as contradistinguished from the *Mekebalim*, *i. e.* the *sticklers* for a *traditional* faith,"—the Ordinary Jews. Their number in the Holy City now only amounts to thirty-two souls, and four heads of families. These *Karaïtes* sometimes visit the *Talmudist* Jews; but they do not intermarry or bury their dead with theirs. "They have no books; the *One Book*, they say, containing the wisdom of the whole world, is *sufficient* for them." They are active and honest, working hard for their livelihood, as they receive but very little assistance from their Crimean brethren.

In conclusion, Mr. Hogg added that since the accounts which some distinguished travellers give of the *fundamental difference* in the religion of the *Karaïtes* from *that* of the ordinary or *Talmudist* Jews vary, it is important for future travellers, who may visit the *Karaïtes*, to determine *what* it is in reality.

On the Application of Colonel James's *Geometrical Projection of two-thirds of the Sphere to the Construction of Charts of the Stars, &c.*

Colonel James exhibited a map of the world on his projection, which is 10 ft. in diameter, and smaller maps of the world, 2 ft. diameter, on which the lines of equal magnetic declination were drawn, and their conveyance round both poles accurately presented to the eye at one view.

After explaining the nature of the projection, which supposes that the spectator is looking into the concavity of two-thirds of a hollow sphere, from a point which would be at the distance of half the radius above the perfect sphere, Colonel James exhibited charts of the stars, pointing out how, from the very nature of the projection, which supposes we are looking into a hollow sphere, it is peculiarly suited for such celestial charts, and also that from the circumstance of its embracing two-thirds of the whole sphere instead of one-sixth, as in the celestial charts on the gnomonic projection, which are in general use and cannot be put together, we have presented to us the whole vault of the heavens at one view, with the circumpolar stars, and every other star to the opposite pole in true relation to each other.

On one of the charts of the stars the "milky way" is exhibited in a manner in which it was never before represented, viz. as a perfect circular band.

The maps, with the magnetic lines and the charts of the stars, are in course of engraving for publication.

On the Roman Camp at Ardoch, and the Military Works near it. By Colonel Henry James, *R.E., F.R.S. &c., Director of the Ordnance Survey.*

The object of this communication was to point out what the author conceives to have been a singular oversight in the writers who have given us descriptions of the Camps and Fort at Ardoch—the "Lindum" of the Romans.

Gordon, in his 'Itinerary,' 1726, says, "This fort of Ardoch I recommend to the public as the most entire and best preserved of any Roman antiquity of that kind in Britain, having no less than five rows of ditches and six ramparts." And again he says, "To the north of the fort of Ardoch are to be seen the vestiges of a vast large ditch upon the moor, with two or three small projections of earth at regular distances, as if they had been made for the outscouts to the foresaid fort."

General Roy, in his 'Military Antiquities,' 1793, gives us a very accurate plan of the fort, and also of the camps on the north of it, to which Gordon refers. An enlarged copy of this plan was exhibited in the Section-room.

Stuart, in his 'Caledonia Romana,' 1845, says, "There is something singular in the arrangement or form of the ramparts at Ardoch station; they did not compose a series of valla, rising in regular successive courses round the larger internal wall, as we find was generally the case elsewhere; but they appear to have been in some places arranged in a very unusual manner."

Chalmers, in his 'Caledonia,' places the site of the great battle "ad montem Grampium," between the Romans under Agricola and the Caledonians under Galgacus, on the rising ground to the north of the great camp, and thinks this is the identical camp which the Romans occupied, and from which they advanced to attack the Caledonians.

In describing the camps to the north of the fort, General Roy considers them to be two marching camps of the Romans, the one capable of holding three legions, or an army of 28,800 men; the other as capable of holding upwards of 12,000 men. On his plan he has represented the Procestrium of the fort, which is a large space of ground enclosed by a rampart for the allies, and connected with the fort, and so arranged that the works of the fort itself command it and could defend it.

The peculiarity in the arrangement of these works, to which both Gordon and Roy refer, consists in this, that the great camp, estimated by Roy as capable of holding 28,800 men, has been constructed in such a way that its ramparts cross not only the area of the more distant camp, described as capable of holding upwards of 12,000 men, but also the area of the procestrium of the fort itself.

Roy says, "From the manner in which the north intrenchment of the camp intersects the west rampart of the great one, it seems to have been a subsequent work." And again, "One thing, indeed, is very remarkable and difficult to be accounted for, namely, that the Romans did not level that part of the intrenchment of the great camp included within the area of the little one, and which, according to appearances, they must have found so troublesome, even from its obliquity, as to have deranged entirely the interior order and regularity of their encampment." And then he goes on to say, "Perhaps, after the separation of the army, this division might be obliged to march in a hurry, without having had time to do it."

It will be observed that Roy supposes that the smaller camp was last constructed; but he says nothing about the larger camp, including a portion of the procestrium of the fort.

According to the view which I take of the subject, I am led to believe that the larger camp was last constructed; and my reasons for dissenting from Roy's views are these:—

Gordon rightly describes the works of the fort as consisting of five ditches and six ramparts; it is in fact seen that the works of the fort consisted of five parallel ramparts and ditches, and that there is beyond these, and not parallel to them, and surrounding only two sides of the north-east angle of the fort, a sixth rampart; and I have no hesitation in pronouncing that sixth rampart to be the work of an *attack* against the fort, and not a work of *defence*.

Cæsar, in describing his attack upon a British fort, says, "Milites, aggere ad munitiones adjecto, locum ceperunt;" and we know the Caledonians over and over again attacked the Roman forts; and I have no doubt that the so-called sixth rampart is the agger or mound, which was in those days the universal mode of attack upon a fort, and which was thrown up by the besiegers without forming a ditch, to command and flank the works of defence.

"The very unusual manner" in which the works are described as arranged at Ardoch, arises from the circumstance that the several writers I have quoted did not observe the fact, that we have at Ardoch not only Roman works of defence, but the works of a besieging army of the Caledonians upon it, a fact which gives a still greater degree of interest to this already very celebrated place. With this view of the subject, the peculiar manner in which the great camps are arranged becomes intelligible. The small camp may indeed have been one of the Roman marching camps; but I cannot conceive how any one could suppose that the great irregular camp which crosses both the smaller camp and the procestrium of the fort could be a Roman work: it is obviously the camp of the besieging army, constructed after the taking of the procestrium. That this great irregular camp was not a Roman camp, must also be obvious to those who read the accounts of the symmetrical manner in which the Romans always constructed their camps, and the proportions they gave them; nor could it be admitted as probable that the Romans would construct a camp and leave for a single night the ramparts of another camp and the procestrium, which irregularly cut up its interior space, and which would, as Roy says, have "deranged entirely the interior order and regularity of their encampment." To the Caledonians this irregularity would probably be of little importance, their chief object being to draw their camp as near to the fort as possible. That the fort at Ardoch was one of those constructed A.D. 84, at intervals, on commanding points, by Agricola, for the subjugation of the country, is I think clearly established; and this station was certainly maintained as a Roman station for three centuries afterwards. The attack upon it was therefore probably made in the middle of the fourth century, at the period of the decline of the Roman power in Britain.

From the circumstance of our finding the great rampart of the attack still standing, there cannot be a doubt that the fort was taken; for if the Romans had been able to resist the attack, their first care would have been to have removed the rampart and restored the procestrium. It is 133 years since Gordon described this fort as "the most entire and best-preserved of any Roman antiquity of that kind in Britain;" and every enlightened lover of his country must feel grateful to the present proprietor, Mr. Horne Drummond, and to those who before him have been the proprietors of the estate at Ardoch, for the careful manner in which it is preserved for the gratification of the students of history.

Extracts from a Letter of Dr. Kirk *to* Alex. Kirk, Esq., *relating to the Livingstone Expedition. Communicated by* Dr. Shaw.

The extracts form the very latest intelligence which has reached England of the intrepid travellers.

After, in a former letter, giving an account of the explorations of the mouths of the river in the steam launch, of their crossing the surf in the launch, and at last getting the 'Pearl' as far up as was thought safe, and of his erecting the iron house on a long narrow island, which they named Expedition Island, and landing the goods, where he was to remain in charge till they could be by degrees transported to Cheepanga, and how, with the return of the Hermes, he sent off several specimens which are now at Kew, Dr. K. proceeds as follows—date, Sept. 22:—

"When I sent my last letter, *viâ* Ceylon, the 'Pearl' had just left, and I was in charge on Expedition Island, while the Doctor was transporting the goods by degrees to Scuna. Here we made ourselves very comfortable. I built the iron house, had the goods all safe, and made a nice open veranda in front, thatched with reeds and covered with tarpaulin, so that we resisted both sun and rain; but of the latter we had very little. The island was a narrow strip, about three-fourths of a mile long, in shape something like an alligator. I made a survey of it, and kept up tide-gauge barometers and thermometers. . . . .

"While our party were busy transporting the goods up to Scuna, war had been going on between the Portuguese and the rebels of the country, and the latter were fortunately thrashed, and fled to the mountain parts opposite Scuna.

"Our chief depôt has been Chupanga, where, in company with Thornton, I have been on detached service. This was for some time the head-quarters of the Portuguese army, and now there are several officers stationed there, whom I found to be very kind fellows, and from whom I received much valuable assistance. I made a trip, while waiting there, to a lake elevated considerably above the Zambesi. During our walk, which took us three days, at the rate of about twenty miles a-day, we met some curious people, but were glad to find all friendly. I returned thus quickly, as I expected the Doctor back from Tete, whither he had gone on his first trip with the powder, which it would have been unsafe to have left in a country at present at war. I received, however, instead, a letter from him, stating that the water is so low at places where the river spreads to an excessive width, that the pinnace could not be taken up at once, until the channel had been previously surveyed by the launch; that the pinnace was left somewhat a little beyond Scuna, in charge of Baines; that the launch would proceed to Tete, return, pick up the pinnace, and afterwards return to Chupanga.

"On hearing this, I had determined on another short excursion, when, to our surprise, up came a boat with two officers of the 'Lynx,' with mails from the Cape. I went off, in company with the officers, to the governor, at the foot of Mounnballer Hills, two days' journey up the river-shore, and was unfortunate enough to come up shortly after he had taken a tremendously fortified place, surrounded by lines of stockades and mud works pierced for artillery and musketry. The rebels must have been many thousands strong, and probably want of ammunition caused them to evacuate the place, otherwise almost impregnable, for the Portuguese got four pieces of cannon (three of them bronze) and an immense quantity of provisions. We found the governor anxious to do anything for us he could, and got from him four canoes to return to the mouth of the river to bring up the things from the 'Lynx.' We escorted the canoes to the mouth of the river, which turned out to be a new one to us, but with so bad a bar that it would have been most imprudent to have attempted to take the canoes over it (though, having a splendid surf-boat, we crossed it all right), for a few days previously the cutter had been upset, and six hands lost out of ten. I now asked the captain to send a boat up the river to catch the Doctor alive and bring him down, which would probably preclude the necessity of his coming down at Christmas, and Mr. Medlicott accordingly set off on this errand, while Mr. Cooke and I set off in the whaler to bring the canoes round to the mouth, by which the 'Pearl' entered, but which had, since that time, changed for the worse. While lying out in the ship, the captain desired us to survey the bar, but after a long cruize we found it quite dangerous to cross, and so put about, intending to return to the ship. After hard work at the oars, we found that impossible, and anchored, and now the seas broke over us so, that we were forced to hoist sail and run through everything, if by any chance we might reach calm water. All day we had nothing to eat but raw pork, and on coming to the bar again it was almost dark, and so rough that it would have been a certain capsize without hope of reaching the shore. So we put about again, determined to beach the boat on the open coast, though it would certainly be smashed under us, in hopes that we might get on shore between the rollers. The surf even then was far too heavy to give us the least chance in the dark, so we stood to sea again, when luckily the current changed, and after three tacks we reached the ship, which we had scarce done when the gale came on in earnest, washing the decks from stem to stern. A few days after, on the gale going down, we descried the boat and launch inside the river. I went off in a boat with the gunner and quartermaster to communicate." [Here follows an account of their crossing the bar, which must have been very bad, for he says that, but for their excellent surf-boat and the steady coolness of the gunner and quartermaster, they would of a certainty have been swamped.] "Here we found the Doctor, and, the next day being much quieter, the whaler went off to the ship.

"You will be glad to hear that this place has not shown itself to us unhealthy. Some of us have been sick, but only for a short time; and for my own part, I have enjoyed as good health as ever I did in England.

"I have had an official letter, thanking me for attending to the sick of the Portuguese army, and have been mentioned in general orders by the Governor of Mozambique; this will always get me along with the Portuguese.

"This work has prevented me from doing much to botany of late, but I have seen a great deal of the country, and am learning the language.

"Our proposed operations are to go to Tete, where the Doctor's brother now is, and which is a fine place, as soon as possible. The launch has been there, and has had the coal in use, which M'Rae says is similar to Welsh coal, and keeps steam well. Bains is in the pinnace working her up Tete.

"*October* 5.—The 'Lynx' has come in all safe, and though she struck on the way is seemingly uninjured. We have had some of her hands with us improving our accommodation and doing repairs; but, best of all, we are to have Walker, the quartermaster of the 'Lynx,' whose first-rate qualities, while up the river and crossing the bar frequently with me had so struck me that I urged the Doctor to apply for him. I know that he is a first-rate man, and will keep the kroomen in their proper place. I have some hopes that we may get another European sailor or stoker; so, if we are as fortunate in him as in our quartermaster, we shall be set up.......We are to go on direct to Tete from this, and will thus clear the Delta before the unhealthy season comes on, and, we hope, be out of the reach of the fevers. We expect to be off to Tete to-morrow."

On the Aboriginals of Australia. By the Hon. T. M'Combie.

On the Native Inhabitants of Formosa. By Dr. M'Gowan.

On Chinese Genealogical Tables. By Dr. M'Gowan.

The Russian Trade with Central Asia. By Thomas Michell, *F.R.G.S.*

The march of civilization in the rear of Russian caravans, military detachments, and scientific expeditions, is rapidly increasing the artificial requirements of the Central Asiatic, creating a greater demand for his produce, and teaching him the advantages of a peaceful, settled life. It may therefore be commercially advantageous, if not politically important, to inquire closely into the habits and circumstances of a population now becoming more accessible from India by the extension of railways, the improvement of roads, and the increased navigation of rivers. Russia is, moreover, beginning to suffer from the short-sightedness of her restrictive tariff on foreign manufactures, which, by fostering the production of the most inferior home articles, has kept the art in its infancy.

Russian manufactures in wool and cotton have hitherto commended themselves in the Turan by their extreme cheapness, having been also in a measure favoured by the influence which the Russian trader commands as a customer for the principal staple of the country; but the natural consequence of improved civilization and increased wealth, derived by Central Asia from the trade with Russia, is the growth of a demand for manufactures of a superior class, such as only England can cheaply produce with the aid of perfect machinery and abundant coal. At the same time, it is reasonable to suppose the effect of the impending emancipation of the serfs will be to raise the price of labour and commodities in Russia; which will necessarily affect the present cheapness of the coarse fabrics of that country. The inferiority of the Russian manufactures offered to the Asiatic in return for his cotton, madder, and other productions, induces him to seek payment in metallic currency. Added to this, the insufficiency of the rude coinage of Turkestan to supply the increasing demands of trade, or to represent the accumulating wealth of the country, has contributed to raise the value of Russian specie to a premium of about 22 per cent. above its value at home. It is thus that the amount of bullion and coin exported from the Orenburg line of frontier between 1840 and 1850 amounted to £229,554, or £6500 more than the exportation of cottons during the same period, and nearly three times that of woollens. The exportation of gold and silver specie to the various countries of Asia had increased from £478,357 in 1847 to £897,691 in 1857.

Metals and hardware are abundantly supplied by Russia to Bukhara, Khiva, and Kokan, and, taken with specie and bullion, form very little less than one-half of the yearly exportations. The metals are red copper, in blocks, and brass, manufactured; iron, wrought and cast, in scrap bars and sheets, and manufactured into locks, staples, knives, trays, and various small articles. The quantity of copper exported to Central Asia between 1840 and 1850 amounted to 603 tons, of the value of £49,675; while the supply of iron, wrought and manufactured, reached £69,000. The hardware consisted of needles, penknives, large clasp-knives, razors, scissors, with joiners' and carpenters' tools. Needles are demanded in very great quantities, and sell at 18*s.* to 21*s.* per packet of a thousand. Knives are articles of ornament as well as of use: they are seldom higher than 4½*d.* each; the ordinary price of a two-blade, double-edged knife being 1¾*d.*, or 1*s.* 8*d.* to 2*s.* 1*d.* per dozen. The razors supplied by Russia to Central Asia are of a class "only made to sell," being purchased at Nijni-Novgorod fair at 2*s.* 6*d.* the dozen, or about 5*d.* the pair; a better description are produced at 3*s.* 6*d.* the dozen, the highest at 5*s.* 2*d.*

The cottons which Central Asia requires are not those for ordinary or common use, but prints and calicoes of rather superior workmanship, and good, vivid colouring, as articles of luxury and artificial necessity. What Russia now produces in the shape of cottons is really too inferior when cheap, and too dear when good. The highest prices given at Nijni-Novgorod fair for cotton prints prepared for the Asiatic market, are 5½*d.* to 5¾*d.* per yard. A piece will contain 35 to 36½ yards, with a breadth of 20 or 21 inches; the weight of each is about 4½ lbs.; so that the gross weight of a camel's load, or 200 pieces, will be about 8 cwt. To this day, certain descriptions of Russian cottons are imposed on the Asiatic as English manufactures, fetching 10½*d.* to 11¾*d.* per yard, when Russian best qualities will only sell at 6*d.* to 6¼*d.* per yard. Calicoes and ginghams are much used in Central Asia. In Bukhara, ordinary quality calico sells at 12*s.* to 18*s.* per piece of 10 to 12⅔ yards, and the best (*called English*) at 24*s.* At Khiva the prices are 9*s.*, 12*s.*, and 15*s.* A kind of nankeen, manufactured from Nos. 20 to 22 for the warp, and 24 to 26 for the woof, is in great demand. Considerable quantities of a cotton, friezed material, known in the trade as plush, are exported to Bukhara and Khiva; it is much used in the uniforms of the soldiery of those countries. In Khiva this article sells at 10½*d.* to 1*s.* 2*d.* per yard. The total declared value of the exportations of Russian manufactures in cotton amounted, between 1840 and 1850, to £223,181.

The cloth and woollens supplied to Central Asia are the produce of Russian flocks, and therefore form a branch of industry perfectly indigenous to the country, and intimately connected with its agrarian wealth. But, as in the case of cottons, Russia enjoys an advantage over foreign woollens only in low-priced fabrics, ranging not higher than 5*s.* 9¼*d.* per yard. With foreign cloths above that price she cannot compete; and the finer the material, the greater the difference in the relative cost of production. Prepared with the sole view of cheapness, these cloths are purchased at Nijni-Novgorod fair at 1*s.* 10*d.*, 2*s.* 8*d.*, and not higher than 3*s.* 10*d.* per yard, in pieces of 17 yards, of a breadth of 1¼ yard. The principal colours are crimson, green, violet, olive, and light-blue. In Bukhara, cloth fetches £3 12*s.* to £4 16*s.* per piece of 20 yards. Between 1840 and 1850 the Russian exportations of woollen manufactures amounted to 485,875 yards, at an average price of 3*s.*

The remaining items in the Russian export trade to the countries of Central Asia are, manufactures in silk, leather, skins, furs, sugar, and other miscellaneous manufactures and small wares. Among the latter, special mention may be made of small mirrors, rouge, and violet powder.

In return, Russia obtains raw cotton, cotton yarn, and some native manufactures in cotton, consumed by the Mahomedan population and the inhabitants of the south-eastern portions of the empire. It is a striking fact, that the Russian demand for these native manufactures is three times the value of the Asiatic importations of Russian cottons. The cotton of Kokan has a staple about ·875 inch in length; the Bukharian has an average length staple, and that of Khiva is more than 1⅝ inch long. When the crop is good, cotton wool may be purchased in Khiva at 10*s.* 4*d.* per cwt., and in Tashkend and Bukhara at 18*s.* 9*d.* When the crops fail, these prices run to 31*s.* and 46*s.* 8*d.* per cwt. The total value of cotton, in a raw state and manufactured, imported into Russia from Central Asia between 1840 and 1850, not including the quantity yearly smuggled, amounted to £1,013,954, or nearly the value of the total exportations from Russia, inclusive even of specie. The other items are silk, raw and manufactured; colours and dye-stuffs, of which the most important are madder, indigo, and lapis lazuli; precious stones and pearls; and other miscellaneous articles, such as dried fruits and sweetmeats, rice, pepper, and semen-contra.

The following comparative statement shows the growth and importance of the trade:—

Exportations to Central Asia in	1849...	£102,203	
,, ,,	1857...	182,039	
			increase £79,836, or 78 per cent.
Importations:	1849.	1857.	
From Bukhara	£79,466	£213,720	
,, Khiva	23,143	43,578	
,, Kokan	81,427	118,907	
	£184,036	£376,205	increase £192,169, or 104 per cent.

The Resources of Eastern Africa. *By* J. Lyons M'Leod, *F.R.G.S.*

Commencing from the eastern limit of the British colony of Natal, the author follows the coast-line to Cape Guardafui, and thence up the Red Sea to the port of Arsinoe or Suez.

After leaving the limits of the Colony of Natal, the first port which attracts attention is that of Port St. Lucia, in latitude 28° 26′ S. and longitude 32° 26′ E.

This port is admirably adapted for throwing supplies of ammunition and also useful commodities into the Zulu country, from which they are carried into the Orange Free State and Trans-vaal Republic, thereby eluding the customs' dues payable at the Cape of Good Hope and Natal.

A considerable trade of this description is already established by several mercantile houses at the Cape of Good Hope; and, this fact having become known in the City of London, merchants are naturally inquiring what articles of trade are suitable for a port where no duties whatever are levied, and where the returns of ivory, hides, horns, and hoofs are immediate.

As the colony of the Cape of Good Hope pays annually to the Boers £5000 sterling as compensation for the duties levied on commodities passing through that colony to the Orange Free State and Trans-vaal Republic, it is natural to expect that the revenue of that colony should be protected by obtaining possession of a port at present belonging to no country, and which offers a sore temptation to the Boers, ever on the look-out for an outlet for their productions, without passing through and enriching a country from which they *trecked* in consequence of real or imagined wrongs.

From Port St. Lucia proceeding northwards, we pass a line of coast, of which we absolutely know nothing, excepting that the country lying between Natal and Delagoa Bay has been for a long time in a most unsettled state, causing numbers of the natives to flock into the British colony of Natal to avoid the massacres which daily take place under the dominion of the ruthless savage Panda, the Supreme Chief in that district.

To the northward of Cape Colatto, which is in latitude 26° 4′ S. and longitude 33° 1′ E., is Iniack Island, which, as one of the dependencies of Tembe, was ceded to Capt. W. F. Owen, R.N., in 1823.

This island, from its position, is admirably adapted for a lighthouse, for the requirements of the steam postal communication between Aden, Natal, and the Cape of Good Hope.

The Island of Iniack is about 240 feet in height; it is open on all sides to the spacious Bay of Delagoa, and the Indian Ocean; and is entirely free from the *miasmata* which surround the neighbouring Portuguese settlement of Lourenço Marques.

The neighbouring country of Tembe, embracing the river Mapoota and the south side of English River, was ceded to Captain W. F. Owen, R.N., by King Keppel in 1823, and, with its dependency Iniack Island, gives us possession of the south part of Delagoa Bay, and also access by water to the Zulu country.

In 1856, the British cutter 'Herald' of Natal purchased from the natives of this district some bags of orchella-weed, for samples, at the rate of two shillings for an arroba of 32lbs, and, on the same vessel returning to Lourenço Marques, in 1857, the same quantity was selling for two Spanish dollars, and a barque was lying there almost wholly laden with it and ivory from the Zulu country and Tembe; the latter being a British possession, which the Portuguese officials would not allow the British Cutter 'Herald' to trade with, excepting on the condition that she would pay dues to the Portuguese Custom House at Lourenço Marques.

In 1857, this same cutter 'Herald' proceeded up the King George or Manakusi river a distance of 110 miles. From the depth and volume of water, and velocity of the stream, as far as ascended by the 'Herald,' it is the opinion of some that this is the outlet of the Limpopo; and the attention of the mercantile world is naturally attracted to a large river which opens a vast tract of country to our merchants.

Proceeding northwards, we arrive at Inhambane, in latitude 23° 52′ S. and longitude 35° 25′ E., at present the resort of slavers under every denomination. This town, situated at the mouth of a large river, hitherto unexplored, so admirably adapted for the export of all the valuable productions of the interior of Africa, requires only the fostering of legitimate traffic to become a great emporium for trade.

The Bazarutto Islands, in latitude 21° 30′ S. and longitude 35° 33′ E., have been long celebrated for the pearls to be obtained there. From accounts which I have received, I am led to believe that the pearl fishery at these islands, properly worked and protected, would rival that of Ceylon. The Portuguese appear to keep possession of these islands merely to prevent other nations from obtaining the pearls, which are entirely neglected by themselves.

To the northward of these islands, in latitude 20° 11′ S. and longitude 34° 46′ E., Sofala is situated, at the mouth of a river of the same name, leading to the auriferous portion of Eastern Africa.

This Sofala is the ancient Ophir of Solomon, in whose days ships were sent from Tarshish to obtain gold from mines which are even now productive, but are entirely neglected, owing to the Portuguese officials finding it easier to enrich themselves by selling the natives of the country than by employing themselves and their slaves in obtaining that metal so much coveted by civilized communities. The only gold at present sent from Sofala is a small quantity occasionally picked up on the surface of the earth after heavy rains.

On both banks of the river Sofala, and from that river northwards to the southern bank of the Zambesi, the country is one mass of mineral wealth; gold, silver, copper, and toward Tête, even iron and coal being found in abundance.

In these vast regions are mines almost innumerable, still productive, but requiring the stimulus of demand, which it is not the interest of the Portuguese officials to create while they can become rich by the slave-trade.

Ruins of cities, once the dwelling-places of nations mighty in their industry, are to be seen in this region, perhaps telling the history of those who provided gold for the Temple of Solomon.

Whether these cities were founded by the Arabs, the Hebrews, or the Phœnicians, who all obtained their supplies of gold from Sofala, or were inhabited by people belonging to Africa, they are existing monuments of nations who, at a very remote date, must have reached a high state of civilization.

Feeling deeply interested in this matter, I did all in my power when at Mozambique to obtain information about the kingdom of Sofala, which resulted in the Governor General of Mozambique publishing an official account of the mines known to the Portuguese in that neglected district. This account gives a long list of gold, silver, copper, and iron mines, which have been worked, but are now entirely neglected, as the country is destitute of labour, the Portuguese having drained it to supply the slave-trade of the Brazils, Cuba, and America. Previous to the Portuguese appearing on the east coast of Africa, the kingdom of Sofala was greatly depopulated by the invasion of the Lindens, and I am under the impression that it was during that invasion that the cities referred to were destroyed.

The mines in Sofala still have attached to them, in the legends of the country, the names of the discoverers, and these names are supposed to be those of the kings who reigned there when the mines were first opened.

In this report it is stated that 500 leagues from Seña there are the remains of large edifices which indicate that they were once inhabited, but by whom is not known*.

This confirms the statement of Barros in his description of the ruins of the City of Zimboë, who states that there are the remains of a fort built of well-cut stones, having a surface of twenty-five palms in length, and a little less in height, in the joining of which there appears to have been no lime used. Over the door or entrance of this fort is an inscription, which some Moors, well-versed in Arabic, could not decipher; nor were they acquainted with the character of the writing.

Around this edifice there are other erections similar to it, having bastions of stone uncemented by lime, and in the middle of them there is a tower at least seventy feet in height. These edifices are called in the language of the country Zimboë, which signifies a royal residence.

I was always told at Mozambique that the Arabs could not decipher the inscriptions to be found on these ruins.

Barros thinks that this country of Sofala ought to be that designated by Ptolemy *Agyzimba*. Zimboë, the name given by the natives to these ruins, certainly offers some affinity to that of Agyzimba. It may be that the inscriptions to be found there, seen only, as yet, in modern times, by the Moor and the unlettered savage, may record truths as interesting as those conveyed in the Adite inscription, engraven on the rock at Hisn Ghorâb.

Proceeding northward, we arrive at the mouths of the river Zambesi, the great commercial highway of East Africa.

This river is navigable for river-steamers of a large burden and light draft of water for at least eight months out of the year; in those parts where it is of great breadth, and consequently shallow, it offers some slight impediment to navigation, from the uncertainty of the positions of the banks, which change their appearance and dimensions during the annual inundations of the low districts. By taking advantage of the dry season, when the body of water in the river is comparatively small, and staking the river, so as to confine the water in a narrower channel, the obstruction to easy navigation may be overcome, and access obtained for at least eight months of the year to Tête, opposite to which town coal may be obtained in abundance. At the same town on the Karuera mountain, 2000 feet in height, which almost overhangs the town of Tête, enough corn may be grown to supply the whole of Southern Africa, and even at this time 6000 Portuguese bushels of corn are exported from Tête.

Along the banks of the Zambesi the gutta-percha and india-rubber trees are found in great plenty, and also the poppy yielding opium.

* Boletim do Governo General de Moçambique, Dec. 12, 1857.

The sugar-cane grows to an enormous size and yields much saccharine matter.

Indigo, roots, and nuts supply colouring matter of various hues, and are in common use among the natives.

Around Sena, where the Zambesi spreads itself over great tracts of country, creating swamps and causing the malignant fever and ague of that country, the antidote is to be found in abundance in the bark of a tree, which yields one of the most valuable articles of commerce, namely *cinchona* bark.

The delta at the mouth of this river affords a subject of deep interest; its growth being so rapid, that one is led to the belief that it is, comparatively speaking, of recent formation. I am inclined to think that it has, in some places, increased as much as five miles since 1821. This appears enormous even when compared with the delta of the Danube, but it must be borne in mind that nature has provided it with the mangrove tree, which from its formation appears to have been specially provided for the purpose of piling up the deltas of rivers.

The mangrove tree grows only in brackish water; that is to say, half salt and half fresh water; and has this peculiarity, that it will not grow in either fresh or salt water. It bears a nut, which, when ripe, from the heat of the sun, bursts with a report like a musket. Some years ago, when employed on boat service in the rivers on the west coast of Africa, in chase of slave vessels, being detached from the other boats of the ship to which I belonged, the bursting of these nuts on a calm sultry afternoon has often led me to the belief that the other boats were engaged in an action with some slaver in another part of the river.

After the nut has burst three young shoots are thrown out; these make immediately for the water, on reaching which they form a small pile, stopping leaves, grass, and mud, floating down, in which they take root and then throw out branches upwards, similar to the banyan tree. It may be easily imagined how soon a delta will increase its demensions when assisted by the mangrove tree. It is certain that Killimane is further inland than when first traded with by the Arabs in the twelfth century; and a knowledge of the time required for the formation of that delta might lead us to estimate the date when the Zambesi burst through the Lupata mountains, and those changes took place by volcanic agency which have given to Central Africa that physical formation so wisely foretold by Sir Roderick Murchison, and subsequently confirmed by the persevering discoverer Livingstone.

Passing on from the mouths of the Zambesi, with all its untold treasures, we come to a country, which, having abandoned the slave-trade, and entered into legitimate commerce, finds its reward in growing richer and more powerful every year; while the neighbouring Portuguese settlements, abandoned to the nefarious traffic in human beings, become annually more impoverished.

The kingdom of Angoxa, latitude 16° 39′ S. and longitude 39° 46′ E., having a seaboard of ninety miles and reaching into the interior for upwards of 180 miles, has in a few years, by abandoning the slave-trade, shaking off the pretensions of Portuguese dominion, and developing the resources of its natural productions, risen to the position of a free and independent kingdom, whose trade is open, on its express invitation, to the civilized world.

Already it supplies immense quantities of simsim, or sesame, or *gergulin* seed (which appears here particularly to thrive), the oil expressed from which is a valuable article of commerce, being used as a substitute for olive oil, and much prized for the finer portions of machinery.

Ivory in abundance, ebony, orchella-weed, gum-copal, cocoanut oil, coir, groundnuts, form the principal portions of the cargoes of fleets of dhows trading in the season between this country and the dominions of the Imam of Muskat. The Sultan of Angoxa asks for a British Consular Agent, and is anxious to place himself under the protection of Great Britain: meanwhile, the Mozambique Government threatens the seizure of English vessels trading with Angoxa.

When Great Britain recognized the territorial rights of Portugal on the east and west coast of Africa, she reserved to British subjects the right of trading with the natives: and whenever these rights are interfered with, prompt measures should be adopted for enforcing full and immediate satisfaction to the injured parties.

The city of Mozambique is situated on an island of the same name, in latitude 15° 2′ S. and longitude 40° 48′ E., which, with two other islands, St. George, and St.

Iago, placed in an inlet of the Indian Ocean, form, with the mainland, a secure harbour five miles deep and five miles and a half broad; and, with the neighbouring harbour of Mocambo, in which three rivers discharge themselves, is, perhaps, the most eligible spot to establish an immense trade with the interior, and an emporium for European merchandise.

The natives from the far interior bring down to Messuril on the mainland, opposite the city of Mozambique, every year, gold, silver, ivory, wax, skins, and malachite, the latter in considerable quantities; showing that there are mines of copper in the Monomoises' country.

In 1856 many of these natives, who came down to trade, were seized by the Portuguese, to supply the (so-called) French free-labour emigration; since which occurrence they have not made their appearance at Messuril.

When Mozambique was in the hands of the Arabs, an important trade was carried on between it, Arabia, and India; but for the last two hundred years, under its present rulers, the trade, principally carried on by banyans to Cutch and Goâ, has been gradually decreasing,

At present it exports ivory, annually 250,000lbs., bees-wax, sesame-seed, orchella, rhinoceros-horns, cocoanut oil, castor oil, ground-nut oil, coir, arrowroot, sago, coffee, tortoiseshell, indigo of an inferior quantity (from ignorance in manufacturing it), and a spirit made from the cachu.

There are large plantations of cocoanut trees, which for the last three years have been much neglected; coffee plantations, likewise in the same position; and a coir-manufactory has for the same period of time ceased to work:—all this caused by the new impetus given to the slave-trade under the denomination of French free-labour emigration, which was established in 1854.

Some few of the residents at Mozambique I induced to clear away and cultivate the cotton shrub; and, with the intention of encouraging legitimate commerce, I wrote to Her Majesty's Ambassador in the United States, and also to the Chamber of Commerce of Manchester, asking for the three descriptions of cotton seeds; viz., the *nankin*, *green seed*, and *sea-island*; intending to send the two former into the interior, and to plant the *sea-island* on the coast where the saline breezes from the ocean, and humid atmosphere from the warm gulf stream, running along the whole of the east coast of Africa, would favour its growth.

Having discovered the mulberry-tree, and that it was indigenous to the soil, I wrote to England for eggs of the silkworm, and addressed a letter to His Excellency the Governor of Bombay, praying his Lordship to send me some eggs of the Tussah and other moths indicated in my letter.

Similarly, I drew the attention of His Excellency the Governor-General of Mozambique to a very important discovery which I had made, and of which the Portuguese were entirely ignorant, viz., that both the gutta-percha tree and also a tree yielding india-rubber were to be found in large numbers on the banks of the Zambesi; and, after having pointed out to him the commercial value of these trees, I begged him to issue an order forbidding any gutta-percha trees to be cut down, but instead, pointing out that they should be tapped longitudinally, by which the supply would indeed be less, but permanent; whereas, if cut down for the purpose of extracting the juice, these trees, as at Singapore, would, in the course of a few years, disappear.

Ibo, in latitude 12° 20′ S. and longitude 40° 38′ E., is admirably situated for trade. At present it is the great warehouse for slaves.

Zanzibar, in latitude 6° 28′ S. and longitude 39° 33′ E., exports gold, ivory, drugs, coir, cocoanut, gums, bees-wax, tortoiseshell, spice, rice from Pemba, sesame-seed from Angoxa, and a great quantity of timber annually to the Red Sea and Persian Gulf.

In 1818 cloves were introduced into Zanzibar from Mauritius: they thrive so well, that the cultivation of them has in a great measure superseded that of the sugar-cane, and even the cocoanut.

Mombas and Melinda are both well adapted for trade, which at one time was of considerable importance between these places and India and Arabia, but Melinda, in less than a century after it had been conquered by the Portuguese, ceased to be a place of any importance.

Lamu, in latitude 2° 15′ 45″ S. and longitude 41° 1′ 5″ E., is a place of considerable trade, more especially in hides and the general exports from Zanzibar. Brava, in latitude 1° 6′ 40″ N. and longitude 44° 3′ E., carries on a considerable trade with India and Arabia, and a rapidly increasing one with America.

The exports are: hides, bullocks, horses, and camels, oil from the joints of camels, salt-beef, great varieties of the skins of wild animals taken by Gallas who go from Zanzibar to Cape Guardafui. Small horses purchased here at from five to six dollars each will realize from sixty to seventy dollars at Mauritius.

The Sumalis inhabit the sea-coast from the equator north round Cape Guardafui to Zeylah; the whole of this vast extent of country is but little known to us.

The kingdom of Kimweri or Usambara, more generally known as the Pangany district, is rich in produce, which may be increased to supply any demand. The sugar-cane is very luxurious, and magnificent forests of timber await the woodman's axe, with the Pangany and its tributaries to carry it to the ocean. Dr. Krapf in speaking of one of these forests says, "This forest is worth millions of money for its fine long and straight timber, being as useful for ship-building as for carpentery." And again: "We descended into a large forest of timber sufficient for centuries to come. The trees are big and straight, from 70 to 100 feet in height."

The recent discoveries of Captains Burton and Speke in the country immediately to the south of this throws a new light on a region hitherto wrapped in the deepest mystery, and gives access into the far interior even to the Victoria Tanganika Lake, and perhaps to the sources of the Nile.

To the northward of Melinda, the river Dana, under the name of Osi, reaches the Indian Ocean. It is stated to flow from the eastern side of Mount Kenia, that it is navigable for boats from the Indian Ocean to the Ukambani country, that there are no rocks at all in the way of navigation, and that even during the dry season the water reaches as high as a man's neck, while during the rains it cannot be forded. Its ordinary breadth is 200 yards, and it is the privilege of the people of Mbé to carry strangers proceeding to Kikuyu, or other countries, from one bank to another.

A small steamer placed on this river would soon open the country to European commerce, and from the source of the Dana to that of the White Nile can be no great distance.

By the Dana or Kilimansi is assuredly the most direct route for settling the great geographical question of the sources of the Nile.

Zeylah or Zeïla, if properly encouraged by the British Government, would be a very good outport, as the descent to that place from the interior is easier than to Massoah, and it is the best outlet of ancient Ethiopia. It is situated opposite Aden, where steam communication would place its productions at once in European markets.

Suez has already become a place of vast importance, foreshadowing the future greatness which awaits it, when the Egyptian transit shall be completed, and leviathan ships like the 'Great Eastern,' on a trunk-line to India and China, will make that port its western terminus, and Suez and Alexandria become the emporia of the East and West.

Having thus briefly stated what articles of commerce Eastern Africa can produce, I feel that it would be a very imperfect notice of this portion of the earth's productions were I to omit the valuable islands on this coast.

In the Mozambique Channel, Europa Island stands conspicuous from its central position in the southern end of this channel. At present it is used as a place of resort for Dhows from the whole of the eastern coast of Africa, to land their cargoes of slaves, awaiting some large European vessel to carry them to their future place of bondage.

This island is well situated for a lighthouse and a depôt which would command the trade of the Mozambique Channel both on the African and also the Madagascar coasts.

Along this coast lies the magnificent Island of Madagascar, called the Great Britain of Africa. It is 900 miles in length and about 300 miles in breadth. From its geographical position, extending from 12° to nearly 26° of south latitude, and the great height of the interior plateaux, being as much as 7000 feet above the level of the sea, it affords a variety of climates, from the humid and oppressive atmosphere of the malaria-districts to the pure bracing breezes of the mountain heights. In the interior of this island the temperature is much cooler than in the low districts near the ocean.

The west coast of Madagascar is indented with bays forming some of the most remarkable and secure harbours in the world, in which there is abundance of water for the largest class of vessels, and nearly all of them very easy of access.

The silk-worm is found in many parts of the island, and the cocoons may be seen in hundreds hanging on the trees, there being no demand there for an article which we go to China for. The natives have always been accustomed to its use in their garments, some of which are very elegant.

Mineral wealth is very abundant, and iron and coal are now found in close proximity. The discovery of coal in Madagascar must soon place that island in the position which it ought unquestionably to hold in the Indian Ocean.

Great Britain alone sends every year 700,000 tons of coal round the Cape of Good Hope, and the Peninsular and Oriental Company expend £600,000 per annum on coal.

Notes on Japan. *By* Laurence Oliphant, *F.R.G.S.*

The three ports of the empire visited by the Mission, and which fell more immediately under our observation, were Nagasaki, situated in the Island of Kinsin; Sowinda, a port opened by Commodore Perry on the Promontory of Idsa; and Yedo, the capital city of the empire. Of these Nagasaki is the one with which we have been for the longest period familiar. In former times it was a fishing village situated in the Principality of Omura; it is now an imperial demesne, and the most flourishing port in the empire. It owes its origin to the establishment, at this advantageous point, of a Portuguese settlement in the year 1569, and its prosperity to the enlightened policy pursued by the Christian Prince of Omura, in whose territory it was situated; while its transference to the Crown was the result of political intrigues on the part of the Portuguese settlers, in consequence of which the celebrated Tageo Sama included it among the lands appertaining to the Crown. Situated almost at the westernmost extremity of the empire, at the head of a deep land-locked harbour, and in convenient proximity to some of the wealthiest and most productive principalities in the empire, Nagasaki possesses great local advantages, and will doubtless continue an important commercial emporium, even when the trade of the empire at large is more fully developed, and has found an outlet through other ports. The town is pleasantly situated on a belt of level ground which intervenes between the water and the swelling hills, forming an amphitheatre of great scenic beauty. Their slopes terraced with rice-fields; their valleys heavily timbered, and watered by gushing mountain streams; their projecting points crowned with temples or frowning with batteries; everywhere cottages buried in foliage reveal their existence by curling wreaths of blue smoke; in the creeks and inlets picturesque boats lie moored; sacred groves, approached by rock-cut steps, or pleasure-gardens tastefully laid out, enchant the eye. The whole aspect of Nature is such as cannot fail to produce a most favourable impression upon the mind of the stranger visiting Japan for the first time. The city itself contains a population of about 50,000, and consists of between eighty and ninety streets, running at right angles to each other—broad enough to admit of the passage of wheeled vehicles, were any to be seen in them—and kept scrupulously clean. A canal intersects the city, spanned by thirty-five bridges, of which fifteen are handsomely constructed of stone. The Dutch factory is placed upon a small fan-shaped island about 200 yards in length, and connected with the mainland by a bridge. Until recently, the members of the factory were confined exclusively to this limited area, and kept under a strict and rigid surveillance. The old *régime* is now, however, rapidly passing away; and the history of their imprisonment, of the indignities to which they were exposed, and the insults they suffered, has already become a matter of tradition. The port of Hiogo is situated in the Bay of Ohosaka, opposite to the celebrated city of that name, from which it is ten or twelve miles distant. The Japanese Government have expended vast sums in their engineering efforts to improve its once dangerous anchorage. A breakwater, which was erected at a prodigious expense, and which cost the lives of numbers of workmen, has proved sufficient for the object for which it was designed. There is a tradition, that a superstition existed in connexion with this dyke, to the effect that it would never be finished, unless an individual could be found sufficiently patriotic to suffer himself to be buried in it. A Japanese Curtius was not long in forthcoming, to whom a debt of gratitude will be due in all time to come, from every British ship that rides securely at her anchor behind the breakwater. Hiogo has now become the port of Ohosaka and Miaco, and will, in all probability, be the principal port of European trade in the empire. The city is described as equal in size to Nagasaki. When Kæmpfer visited it, he found 300 junks at anchor in its bay. The Dutch describe Ohosaka as a more attractive resort even than Yedo. While this latter city may be regarded as the London of Japan, Ohosaka seems to be its Paris. Here are the most celebrated theatres, the most sumptuous tea-houses, the most extensive pleasure-gardens. It is the abode of luxury and wealth, the favourite resort of fashionable Japanese, who come here to spend their time in gaiety and pleasure. Ohosaka is one of the five Imperial cities, and contains a vast population. It is situated on the left bank of the Jedogawa, a stream which rises in the Lake of Oity, situated a day and a half's journey in the interior. It is navigable for boats of large tonnage as far as Miaco, and is spanned by numerous handsome bridges. The port of Hiogo and city of Osaca will not be opened to Europeans until the 1st of January, 1862. The foreign residents will then be allowed to explore the country in any direction, for a distance of twenty-five miles, except towards Miaco, or, as it is more properly called, Kioto. They will not be allowed to approach nearer than twenty-five miles to this far-famed city. Situated at the head of a bay, or rather gulf, so extensive that the opposite shores are not visible to each other, Yedo spreads itself on a continuous line of houses along its partially undulating, partially level margin, for a distance of about ten miles. Including suburbs, at its greatest width it is probably about seven miles across, but for a portion of the distance it narrows to a mere strip of houses. Any rough calculation of the population of so vast a city must necessarily be very vague and uncertain; but, after some experience of Chinese cities, two millions does not seem too high an estimate at which to place Yedo. In consequence of the great extent of the area occupied by the residences of the Princes, there are quarters of the town in which the inhabitants are very sparse. The citadel, or residence of the temporal Emperor, cannot be less than five or six miles in circumference, and yet it only contains about 40,000 souls. On the other hand, there are parts of the city in which the inhabitants seem almost as closely packed as they are in Chinese towns. The streets are broad and admirably drained, some of them are lined with peach and plum trees, and when these are in blossom must present a gay and lively appearance. Those which traverse the Prince's quarter are for the most part as quiet and deserted as aristocratic thoroughfares generally are. Those which pass through the commercial and manufacturing quarters are densely crowded with passengers on foot, in chairs, and on horseback, while occasionally, but not often, an ox-waggon rumbles and creaks along. The houses are only of two stories, sometimes built of freestone, sometimes of sunburnt brick, and sometimes of wood; the roofs are either tiles or shingles. The shops are completely open to the street; some of these are very extensive, the show-rooms for the more expensive fabrics being upstairs, as with us. The eastern part of the city is built upon a level plain, watered by the Toda Gawa, which flows through this section of the town, and supplies with water the large moats which surround the citadel. It is spanned by the Nipon; has a wooden bridge of enormous length, celebrated as the Hyde Park Corner of Japan, as from it all distances throughout the empire are measured. Towards the western quarter of the city the country becomes more broken; swelling hills rise above the housetops richly clothed with foliage, from out the waving masses of which appear the upturned gables of a temple, or the many roofs of a pagoda. It will be some satisfaction to foreigners to know that they are not to be excluded for ever from this most interesting city. By the Treaty concluded in it by Lord Elgin, on the 1st of January, 1863, British subjects shall be allowed to reside there, and it is not improbable that a great portion of the trade may ultimately be transferred to it from Ranagawa. There is plenty of water and a good anchorage at a distance of about a mile from the western suburb of Linagawa. The only other port which has been opened by the late Treaty in the Island of Nipon is the Port of Nee-e-gata, situated upon its western coast. As this port has never yet been visited by Europeans, it is stipulated that if it be found inconvenient as a harbour, another shall be substituted for it, to be opened on the 1st of January, 1860.

On the Yang-tse-kiang, and its future Commerce.
By Captain SHERARD OSBORNE, *R.N., B.C., F.R.G.S.*

The stand-point Captain Osborne wished his audience to take was in the province of Hon-Peh, the central one of China, where a stream from the north-west of about the volume of the Thames joins "the Great River"—Yang-tse-Kiang. They had to deal with eight of the eighteen provinces. Rich in all the products for which China is remarkable, and for which western nations insist upon a trade with her, this zone, whence come all our silks, and nearly all our teas, was for 200 years only reached by an overland commerce from Canton. In 1843, the establishment of trade at Shanghai, on the eastern sea-board of this great central zone, without hardly affecting the overland trade to Canton, proved incontestably the surpassing richness in products of the provinces of Central China, and the great demand there was for European merchants there, if not as sellers, at any rate as buyers. The Great River, a sealed route until 1858, lies opposite the great city of Hankow. On the western bank is Han Yang, also a large city; whilst facing them both, on the south side of the Great River, extends another huge walled city—Woo-Chang-Foo. All three have lately been subjected to a visitation from the Tai-pings or rebels. The latter, the residence of the Viceroy of the two Hu's (Human and Hupeh), a region somewhat larger than France, though far more rich and populous, was all but in ruins when Lord Elgin's squadron visited it. Hankow, however, like all natural commercial emporiums, had evidently revived directly the fires of the Tai-ping incendiaries were quenched; houses, all new, covering, as far as they were able to judge, the entire site of the old town. All the three cities, which stand in one immense plain, with here and there a hill rising out of it, like islands out of the sea, were felicitously described with great minuteness. The river, it was stated, was in no place less than half a mile wide, and the waters still range at the low season from 60 to 42 feet in depth. From this point, 600 miles from the sea, the distance to the source of the river is 2500 miles.

The difficulty of obtaining any information from the Chinese was extreme.

A missionary reported that in the far west provinces, 1200 miles from the sea, he reached the Great River, and found it a mile and half broad, and Captain Osborne thinks there is every reason to believe that it is navigable by native vessels, between Wester Sochow and the great emporium of trade, at the point of which this missionary spoke—Tchoun-King, and that many other rivers running into it are navigable. There are rapids or falls, however, about 160 miles above Hankow, which, unless it is found that they can be surmounted by the aid of steam power, will be the furthest point which vessels can reach, and will divide the river into the upper and lower valley. With a flatter description of vessels, however, Captain Osborne is confident the river will be found to be navigable even beyond this barrier.

The traders' junks, with which they come from all parts of this great empire to Hankow market, find a refuge in the mouth of the river Han. Iron is found in Hankow in great quantity, wrought and unwrought, the best quality, quite as good as Swedish, coming from the province of Hunan, and costing about £14, while the cheapest is sold at £5. It was also smelted with coals, which, from the southern provinces of Hunan, can be purchased out of vessels afloat, at £2 5*s.* to £2 15*s.* per ton. Tea, silk, wax, tobacco, and Chinese grass were to be bought to any extent—the teas from the western provinces. Captain Osborne showed some of the teas to merchants at Shanghai, who declared they were very valuable, but unknown to them even there in trade. The Chinese grass makes clothing, sails, or ropes, and is in great demand for all the purposes to which hemp and flax are applied in Europe. It sold in Hankow for 25*s.* a cwt., and at Ningpo for 55*s.*, a pretty good profit for a distance of 600 miles of carriage by ship, plainly showing that, when once the English get steam set fairly a-going upon the Chinese rivers, they will be able to cheapen even their own articles to them. There were stores full of native manufactured cottons, as well as English ones, the different prices of which, and of silks, linens, and many other articles, Captain Osborne presented in a tabular form for the information of those specially interested in the subject, and from which it appeared that cotton has every likelihood of being the chief article which could be imported with advantage direct from Europe.

Everywhere in Hankow there is a throb of commerce. It seems like what Shanghai was before European merchants resided there, and that it only requires their presence at Hankow to make its trade rival that of Shanghai, which in fifteen years has increased steadily to its present enormous amount of 28 millions sterling. Captain Osborne thinks, however, that English merchant ships can never go up farther than the confluence of the Poyang Lake, 120 miles below Hankow, the meeting of the Takeang and the Poyang Lake occasioning at this point a mass of shallows and banks as well as three or four channels, with more or less water in them. Kew-Keang, which stands at this point, Captain Osborne described as a city rendered important for trade by the great road from Pekin to Canton passing it. When captured in 1853, its trade was very great, and it was extremely rich and populous; when visited by Lord Elgin's squadron, it was a perfect picture of desolation.

It must be at or near Kew-Keang, Captain Osborne says, that Europeans must first establish their great entrepôt for central China. To it their ships can safely reach, especially auxiliary screw clippers, without transhipping their freights. He had no doubt they would find safe anchorage there, and thence their goods would permeate throughout central China, and thus they would prevent a piece of chintz made in Manchester, which sells at Shanghai, 28 yards for 13*s*., from selling, as they saw it at Hankow, at about 13*d*. a yard. But it was very important for reaping the full advantage of the treaty of Tientsin that the Chinese be made to understand that the Yang-tse-Keang, from its mouth at any rate, to Hankow, is ours as well as the Chinaman's highway. It only requires peace between the Imperialists and Tai-pings to make the country around Kew-Keang, embracing much wealth, high cultivation, numerous cities, and countless villages and hamlets, what Captain Osborne says he remembers Nankin to have been seventeen years ago—the garden of China; and it is easy to predict that the wants of this population, and the products of their industry, will yet form a very important item in British commerce with them.

His own impressions Captain Osborne stated to be, that, with handy fast-sailing ships, or, better still, with auxiliary steam ships, there was nothing to prevent them reaching the entrance to the Poyang Lake, by ascending the river in June after the spring thaws, and returning in the rains; and pilots should be established at moderate fees, instead of the present extortionate rates levied by Europeans for the Lower Yang-tze, which Captain Osborne estimated at £30,000 per annum upon English imports and exports from Shanghai alone. Vessels of still smaller size would answer and pay well between Poyang and Hankow. When the entry of the British flag into the Poyang Lake became known to the native merchants of Canton, cotton fell in the market, the Chinese monopolists knowing that the days of large profits were numbered. The trading stations Captain Osborne recommended were Hankow, Kew-Keang, and Nanking or Ching-Keang.

On some curious Discoveries concerning the Settlement of the Seed of Abraham in Syria and Arabia. By Major PHILLIPS.

Notes on the Lower Danube. By Major J. STOKES.

On the Sculptured Stones of Scotland. By JOHN STUART, *Secretary to the Society of Antiquaries of Scotland.*

The author said the occurrence of pillars in almost all parts of the world, to mark events of various kinds, is quite remarkable. The Bible is full of instances of pillars being erected. Those pillars were of two kinds—for marking sepulchres and for marking other events. When Rachel died, Jacob set up a pillar over her grave; and long after that time Rachel's sepulchre is referred to as a well-known spot. This refers only to the class of single stones, however, but we have at least one instance of a group of stones being put up for a historical purpose. When Israel crossed the Jordan, twelve stones were set up corresponding with the twelve tribes. In Scotland we have instances of both classes of pillars—that is, of single pillars, and pillars collected in groups, of circular form; these latter having unfortunately been connected with the Druids without the slightest foundation on which to build such a theory. It was Stukely who first introduced this opinion, which has but tended to obscure the whole subject; and the sooner we get rid of it the better. Mr. Charles Dalrymple, who is well known in connexion with the Archæological Exhibition here, was kind enough to make some investigations in this county, and the following is his account of the results of one of his diggings at Crichie, about 16 miles from this town. The circle had originally consisted of six stones, of which only two are now standing.

Sepulchral deposits were found near the site of all the stones. On digging about one of them standing on the north side, an urn was found inverted, having a small flat stone above it, and another below it, and filled with calcined bones. This urn was about a foot in height, narrowed at the top, and having diagonal lines on the narrow rim for ornament. Near the base of another stone on the same side of the circle was found, imbedded in clay, a circular cist about nine inches in diameter and a foot deep, filled with calcined bones. This cist was shaped like an urn, and was lined with small stones, evidently broken for the purpose. Close to this pit was found a stone celt perforated by a hole for the handle, and at a little distance from this, a deposit of calcined bones uninclosed, and somewhat further to the south an urn. On digging on the south side of the spot where a stone had formerly stood, a small stone cist, nearly square, was found, being about eleven inches by nine, and about sixteen inches deep, with small flat stones at bottom, and half-filled with remains of bones. Close to the former site of another stone, now removed, was found an urn of better workmanship than that formerly referred to, about three and a half inches in width at bottom, and widening towards the top, where it measured about seven and a half inches. At the neck, which was narrowed, there are some traces of ornament of angular pattern, consisting of diagonal lines crossing each other like a St. Andrew's Cross. It was filled with calcined bones, some of them those of animals. Close to the former site of a fifth stone was found a circular deposit of bones in a clay bed, without cist or urn. On digging about the spot where a sixth stone had stood, it appeared that a deposit had been buried near it also, about the usual distance of one foot and a half from it. This deposit, however, had been disturbed, probably by a tree which had been planted close to it. A stone had stood in the centre of the circle, and a digging at this site brought to light a large underground cairn of stones covering a cist. The cairn was about five and a half feet in depth, forty-five feet in circumference at the surface, and thirty feet at the top. The bottom was paved with large slabs of stone, of which those at the sides overlapped the edges of one large one in the centre, which formed the cover of a cist, three feet eleven inches long by two feet ten inches wide. The cist contained a skull at the west end. At the opposite end were the leg-bones lying across the cist. In the centre of the cist were some calcined bones. Above the centre of the cairn, just below the superincumbent earth, was found a deposit of calcined bones, without any urn or flat stone above or below. All the bones found in the circle appeared to be calcined. Those in the urn first referred to appeared to be partly human and partly those of small animals, if not of birds. A human jaw-bone in this urn was unmistakeable—small and delicate like that of a woman.

Thus we find in almost every instance the discovery of sepulchral deposits in connexion with these pillars. These circles may have had other meanings, though this is the only one we can discover. The present paper, however, deals with sculptured pillars, and these consist of two distinct classes. First, there is the rude, unpolished, unhewn stone covered with figures which we call symbols. One of these pillars [a figure of this pillar was given among a series of fine diagrams prepared to illustrate the paper by Mr. Gibb, of Messrs. Keith and Gibb, of Aberdeen] is found at Logie, in this county. It contains various symbols, including 'the spectacle ornament,' and inclines in a position which Irish scholars say is peculiar to this stone.

Mr. Stuart went on to allude to the symbols of a more elaborate character, including the elephant, fish, &c., on others of these pillars, remarking as to the distribution of the pillars, that by far the larger portion of the stones between the Dee and Spey are of the ruder class of stones covered with symbols. In the centre of the district, there is a stone with an inscription upon it which has hitherto baffled the efforts of scholars to state its character; until lately that Lord Aberdeen got it submitted to the late Dr. Mill of Cambridge, who prepared a disquisition on it before his death, which is now in course of being printed. In it, it will be found that Dr. Mill had satisfied himself that the inscription was a Phœnician one; at all events, there can be no doubt that it is Eastern.

This stone, as already stated, is in the centre of the district between the Dee and the

Spey. There is one remarkable fact connected with these symbol-stones—viz. at Norries Law in Fife, near a circle of these stones, there was found what is believed to have been a complete set of armour. The symbols upon the stone were found repeated upon a silver ornament among the relics alluded to. Now, if we could suppose that this symbol—the spectacle ornament—indicated the rank of the individual, or had reference to sacred dignity, it would be a great step gained in the elucidation of these sculptures. It has to be observed that the symbols are never found twice repeated in the same order. Mr. Stuart next proceeded to notice the stone crosses, of which there are some very remarkable examples on the west coast—a beautiful one at Oronsay, and another at Kildalton in Islay. Sculptured crosses, which are of a more recent date than the symbols, occur less frequently on the east coast of Scotland—in the district between the Forth and Caithness; and what is to be remarked in regard to them is, that while in Aberdeenshire the symbol is common, the cross seems to be less prominent; when you go to Forfarshire, there are some magnificent examples of the cross, and the symbol becomes less conspicuous, and its place seems to be occupied with subjects of quite a different description. The stones present many instances of priests in their robes with books, and occasionally with remarkable ornaments. At times these have peaked beards and moustaches—men shooting with the bow and arrow—bird-headed human figures—figures in armour on horseback, having the trapping and armour in detail—men devoured by animals—men seated as if in judgment—historical scenes relative to slaughter—processions, in one of which a man leads an ox, and is followed by other men in line—in another several men and oxen, which, in a third, appear about to be sacrificed; and here the men are tonsured and carry candles. The centaur occurs, occasionally dragging branches of trees, and sometimes carrying battle-axes. A chariot and horseman are seen at Meigle. A single specimen of a boat appears on St. Orland's stone; and there are specimens of monkeys, apes, lions, leopards, deer, and beasts of the chase. The temptation in Paradise occurs at Farnell. There are also inscriptions upon one at least of the sculptured crosses, which, however, appear to resemble the Irish character, although they have not been read to the satisfaction of scholars. In the earliest notice of these stones which we have, we find the ancient inhabitants of Scotland thus spoken of by Boece—"They usit the ritis and maneris of Egyptians, fra quhome thay tuk thair first beginning. For all thair social besines, they usit not to writ with common letteris usit amang othir pepil, but erar with sifars and figuris of beistis maid in manner of letteris, sic as thair epithafis and superscriptions abone thair sepulturis schawis; nochtheless this crafty manir of writing, be quhat stenth I can not say, is perist; and yet thay have certane letteris propir amang thaimself, quhilkis war sem time vulgar and common." Mr. Stuart observed that the sculptured crosses of Scotland were distinct from those in Ireland and Wales, &c., the sculptures in Scotland almost invariably representing hunting scenes, &c., while those in Ireland are drawn from the Bible—as the Temptation, the expulsion from Eden, &c. The symbols of Scotland were mostly unknown elsewhere, nothing similar being found in Britany, Ireland, or Northumberland, while the symbols of the Christian Church are not local but general, and universally understood. And if the Scottish sculptures had been Christian, we should have found them diffused over a wider sphere. Then the Scots who came from Ireland in the sixth century did not use them in their own country, nor in Argyll, the country which they colonized; so that we must suppose the symbols to be the work of the Pictish people, in whose country, with two exceptions, they occur,—one in Galloway, the other discovered by the author's friend Mr. Robertson, in Prince's Street Gardens, Edinburgh. These Picts are spoken of in the third century by Roman authors, when the term Caledonii is given up, and we find them historically in possession of the country till they were overcome by the Scots in the ninth century. There were two nations, the north and south, the former converted by Ninian, the latter by Columba, in the latter part of the sixth century. Much as we hear of their mutual warfare and conflicts with their neighbours from the Irish chroniclers, we yet gather from the venerable Bede some facts which show considerable progress in arts. Biscop, abbot of Yarrow, founded, about 673, a monastery at Wearmouth. He had been at Rome, in company with Wilfrid, about twenty years before, and they both imbibed a taste for Roman architecture, which they afterwards strove to diffuse in their own country. Biscop brought home masons to make him a stone church, after the manner of the Romans, in place of the more perishable structure of wood. About the year 710, Nechtan, king of the Picts, sent messengers to Cœdfrid, the successor of Biscop, to ask for information as to the correct time of celebrating Easter, then a mooted point between the Anglo-Saxon and Scottish churches. The stones occur, then, in the land of the Picts, whoever they were. They are probably the work of their hands; and it is not a violent conjecture to suppose that they mark the period of transition from heathenism to Christianity. If we regard these sculptures as the earliest works of art, and the expression of the ideas of the early inhabitants of Scotland, they must be regarded with great interest. But increased research and more rigid classification may yet draw new and unexpected deductions from them. One great desideratum would be, to have systematic diggings about these pillars, and to preserve the skulls and other remains which may be found in doing so. The time for theorizing from the mere shape and appearance of those monuments, such as those at Carnac in Britany, and our own Stonehenge and Avebury, is quite gone by, and wherever the pick-axe has been used, as it is now in the course of being done in Britany, the result presents us with some, and the first reliable data for any conclusion on the subject. If this agent is judiciously applied to the various classes of our Scottish antiquities which yet remain to us, we may hope to obtain some sure footing for investigating the history of the early inhabitants of our country.

Rapid Communication between the Atlantic and the Pacific, viâ *British North America. By* Major Synge, *F.R.G.S.*

STATISTICAL SCIENCE.

Introductory Address by Colonel Sykes, *M.P., F.R.S., President of the Section.*

The President opened the meeting in a brief address. He said he had been a member of this Section from its commencement, and had been a pretty constant attender—in fact, was one of its founders. The rules of the Section are rigid. No paper is allowed to go before the public that has not been referred to a member of Committee and approved by him, and by the Committee of the Section. The object of this is to ensure the absence of points in religion and politics, always liable to excite bad feeling, or likely to do so. He had therefore little to say, as no one had had the power to question the statements he might make. However, he might safely give a few facts that could not be questioned. The object of the Section was to obtain the condition of facts, expressible in numbers chiefly. Then it rests with those who produce the facts, or others, to draw their deductions from them. Statistics were so valuable, that there could be no safe legislation without them; but they might be turned to disastrous account, so as to become a snare, and to lead to ridicule. He cautioned them to beware of drawing deductions from a period of time less than seven years, and also of generalizing from local facts, even when applicable to a long period.

On the Arts of Camp Life. By Colonel Sir J. Alexander, *F.R.G.S.*

On the Manufactures and Trade of Aberdeen. By G. B. Bothwell.

He traced the history and progress of the manufactures and trade of this city from a very early period. The manufactures consisted principally of coarse woollens and stockings, which were exported to Campvere and Dantzic, and so extensive were these exports in the seventeenth century, that Sir Patrick Drummond, Conservator of Holland, often remarked that "Scotland was more obliged to the town of Aberdeen for returns in money for its trade, than to all the other towns in the kingdom." At this period the exportation of salmon was also very great. In favourable seasons upwards of 1400 barrels of 250 lbs. each have left the harbour.

The Woollen Trade is still extensively carried on, but circumstances, which it is needless to mention, have prevented some of our manufacturers from supplying the details necessary for showing its extent. I may mention, however, that Messrs. Alexander Hadden and Sons employ about 1200 males and females, besides giving partial employment to a very great number of women over a large area of the neighbouring country by giving out worsted to be knitted into hose. There is one department of the woollen trade which of late years has been very largely extended in this city—I mean the winsey manufacture. So far as I have been able to ascertain, there are about 400 looms employed in this department alone. Each loom will turn out about forty yards weekly, and the weaver will receive 3½*d.* per yard on an average. Expert workmen, when inclined, will make double the above—but these are exceptional. It thus appears that the annual produce of these looms is upwards of 800,000 yards, while the wages paid to the weavers amount to about £235 weekly.

The Cotton Manufacture, embracing the spinning, weaving, bleaching, and printing, was extensively carried on here for many years; but the only cotton-spinning establishment now in Aberdeen is that of Bannermill, belonging to Messrs. Robinson, Crum and Co. The number of male work-people employed by them is sixty-six, and the average wages 12*s.* 7*d.* per week. The number of female workers is 579, and the average wages 4*s.* 4½*d.* per week. Their finer yarns are principally sent to India, whilst, to a small extent, Germany consumes their coarser sorts.

Perhaps there is no better example of the astonishing power of machinery than Bannermill affords. It is only about eight years since it was purchased by Messrs. Robinson, Crum and Co. When in the hands of the previous owners, the quantity of cotton spun was about 1,117,000 lbs. yearly; whereas the first year after it was in the hands of the present owners, the quantity was increased by 112,459; and last year, by an increase of only four male and five female workers, the quantity was increased by 320,570; and the year ending July last, the increase—*almost solely by additional machinery*—was no less than 599,000, or an increase of more than *one-half* the quantity manufactured by the former owners with about the same number of hands.

The Linen Manufacture.—During the latter half of last century several extensive linen manufactories were established. The only one now existing was established by the late Mr. Maberley, and now belongs to Messrs. Richards and Co., of London, with the Rubislaw Bleach-field.

The number of male work-people employed at these works is about 622, with wages varying from 4*s.* to 8*s.* for boys, and rising to 21*s.* and 28*s.* with age and experience.

The number of female workers is about 1614, with wages varying from 3*s.* 6*d.* to 4*s.* 6*d.* to the younger girls, and rising to 7*s.* 6*d.* and 8*s.*, and a few as high as 9*s.*

The quantity of flax, tow, and jute manufactured weekly, is about 50 tons, or 2500 tons yearly.

Besides manufacturing large quantities of yarns for exportation to Spain, Italy, Germany, and Denmark, they manufacture linens of all kinds, especially the heaviest or common Scotch classes, such as canvas, household linens, &c. These are exported to all parts of the world, the chief markets being North and South America, the West Indies, and Denmark. They frequently undertake Government contracts for linens for the army and navy.

The Tape-work.—The manufacture of tape has been carried on here for many years by Messrs. Milne, Low and Co. They employ upwards of 100 work-people, chiefly females, and the wages vary from 4*s.* to 18*s.* weekly. The quantity made approaches to 20,000,000 yards yearly, and the home and colonial markets are principally supplied by the Aberdeen manufactory.

The Paper Manufacture.—The extensive paper-works at Stoneywood, carried on by Messrs. Alexander Pirie and Sons, were established nearly 100 years ago. Till the year 1848, they confined themselves almost solely to the manufacture of printing paper; and the quantity of raw material used was from 650 to 700 tons yearly, while the number of male work-people was from seventy to eighty, at wages varying from 11*s.* to 18*s.* weekly; and the number of females was about 100, with wages varying from 5*s.* to 7*s.* In 1848, however, they enlarged their works to a very great extent, or rather, I should say, they rebuilt them upon a much more extended scale; and they now are principally engaged in the manufacture of writing-papers. They use about 2500 tons of rags yearly, a great part of which is brought from Germany. The number of males is increased to about 300, with wages at from 14*s.* to 21*s.*; and the females now number from 700 to 800, with wages from 5*s.* 6*d.* to 8*s.* weekly.

Besides the home trade, they largely supply America, Australia, and India.

They were the first to introduce the manufacture of envelopes into the North of Scotland; and, by the aid of machinery, they can now make 3,000,000 envelopes weekly.

The only disadvantage they lie under is the expense of coals; but, on the other hand, they possess an abundant supply of pure water from the Don, which, in the manufacture of paper, must be of vast consequence.

An extensive manufacture of wrapping-paper is carried on in the same neighbourhood by Messrs. Charles Davidson and Sons.

Comb Manufacture.—As a very full and interesting account of the Aberdeen Comb Works appeared a few years ago in 'Chambers's Edinburgh Journal' (No. 396, New Series, Aug. 2, 1851), it will not be necessary for me to do more than give the statistics of the works of Mr. Stewart (formerly Messrs. Stewart and Rowell). These works were established about the year 1830, and have been conducted on a very extensive scale since that period. Not only was steam-power first employed here, but the division of labour, and many important improvements and inventions were brought into successful operation by the energetic proprietors. The materials employed in the manufacture of combs are tortoiseshell, horns, and hoofs.

As a curious illustration of the value of labour, we give the following comparative estimate of the produce of the three materials:—

	Increase per cent.
1 cwt. shell, val. £200, produces combs, val. £275	$37\frac{1}{2}$
1 ton horns, „ 56, „ „ „ 150	168
1 ton hoofs „ 12, „ „ „ 36	200

Regarded in this aspect, in the relation of labour to material, we find that hoofs—intrinsically the least valuable of the three materials—become, with the application of labour, the most valuable, that is, proportionally; and the converse holds good in the case of tortoiseshell.

I may add that tortoiseshell has fallen in price considerably since the above table was drawn up, but the proportion between the original value and the labour remains about the same.

The different kinds and sizes of combs amount to between 2500 and 3000, and "the aggregate number produced of all these different sorts averages upwards of 1200 gross weekly, or about 9,000,000 annually—a quantity, that, if laid together lengthways, would extend to 700 miles."

The annual consumption of ox-horns is about 730,000, being considerably more than half the imports a few years ago. The annual consumption of hoofs amounts to about 4,000,000. The consumption of tortoiseshell and buffalo-horns, although not so large, is correspondingly valuable. Even the waste, composed of horn-shavings and parings of hoofs, which, from its nitrogenized composition, becomes a valuable material in the composition of prussiate of potash, amounts to 350 tons in the year; and finally, as the crowning illustration of the enormous extent of these comb-works, the very paper for packing costs £600 a year.

The following may be given as an example of the extraordinary reduction in the cost of combs effected by the power of machinery and the division of labour:—Side-combs are sold retail at 1*d.* per pair—an article, that, in its progress from the hoof to the comb, undergoes eleven distinct operations. This comb, then, which, thirty years ago, was sold to the trade at 3*s.* 6*d.* per dozen, can now be purchased, in the same way, for 2*s.* 6*d.* per gross! thus effecting a reduction in price of about 1600 per cent.

There are employed at these works about 500 men and boys, and 200 females—in all 700, or about four times the number employed in the comb-trade in all Scotland when the business was commenced.

The wages vary from 18*s.* to 25*s.* for men; boys and apprentices from 3*s.* to 4*s.*, and 10*s.* to 12*s.*; girls, from 4*s.* to 9*s.*

The comb-workers, some years ago, were noted for their dissipated habits, but it is gratifying to learn that a great improvement has been effected in this respect, and they are now, in general, as well-behaved as the other working-classes of the city. This change speaks much for the success of Mr. Stewart's efforts in behalf of the moral and physical improvement of his work-people.

The comb-manufacture is also carried on with great spirit and success by Messrs. John M'Pherson and Co. They employ from 170 to 200 male work-people, and from 50 to 60 females.

The quantity of raw materials used annually is about 350,000 horns, and 700,000 hoofs.

I may add, that the change in fashion—the mode in which ladies dress their hair—has of late materially affected the comb trade, and its extent is not nearly so great as it was a few years ago. The next change of fashion, it is to be hoped, may bring about a revival in this important trade.

Quill Manufacture.—Considering the almost universal use of metallic pens, it is surprising to find that the manufacture and sale of quills continue to be about as great as ever. Indeed, the progress of education, and perhaps more than anything else, the introduction of the penny postage, have caused such an increased use of the pen, that, had not metallic substitutes been adopted, all the geese in the world could not have supplied the demand. The Aberdeen Quill Manufactory is the only one of any extent in Scotland. It was established about forty years ago. Several millions of swan, goose, and crow quills are annually manufactured; and, besides supplying the home market, they are largely exported to India, America, and the Colonies. The countries from which the raw material is imported are Russia, England, and Ireland; and the price continues to be about the same as before the introduction of the steel pen.

Harbour and Railway.—Perhaps there is no better criterion for showing the progress of the trade of the city than by a statement of the shore and harbour dues on goods and shipping during the last fifty years. These amounted in

1810	£6,443	1850	£17,069
1820	7,711	1851	15,127
1830	10,744	1858	19,036
1840	15,516		

From these figures it will be seen that a gradual increase has taken place in the Shore and Harbour Dues since 1810, with the exception of the year 1851, when a reduction of about £2000 took place. This is explained by the circumstance that the South Railway was opened, and had been in full operation during the whole of that year. But it is gratifying to find that the revenue of the harbour is now about as high as it ever has been—thus showing that during the last eight years the trade of the city has been increased by about the whole of the railway traffic.

Shipping.—This subject will, I trust, be taken up separately, as it is one that deserves to be fully illustrated, seeing that the fame of the Aberdeen "clipper bow," and the high character of the Aberdeen ship-builders have been spread to all quarters of the world.

I shall therefore confine myself to a statement of the progressive increase of the ships belonging to the port:—

Years.	Vessels.	Tons.	Average Tonnage of each ship.
1656	9	440	49
1760	45	2,453	$54\frac{1}{2}$
1800	270	21,215	$78\frac{3}{4}$
1840	192	32,361	168
1850	252	53,129	210
1858	260	71,000	273

From this statement it will be observed that, while the number of ships since 1800 has slightly decreased, the tonnage has been more than tripled. In 1800, the average size of each ship was only $78\frac{3}{4}$ tons, whereas the average is now 273 tons; while the whole tonnage of the port in 1800 was only 21,215, it is now 71,000.

Since the year 1810, when the principal improvements on our harbour commenced, there has been expended upon it about £600,000.

Imports and Exports.—The imports show also a considerable increase. The following are the quantities of coals in bolls of $5\frac{1}{2}$ cwt. each:—

	1840.		1850.		1858.
English........	403,532	....	421,844	....	444,811
Scotch	66,238	....	94,552	....	82,971
	469,770		516,396		527,782

And during the last year there were brought by railway 18,298 tons of Scotch coals

Timber.—The quantities of timber in loads of fifty cubic feet each were as follow:—

	1840.		1850.		1858.
American	4,976	....	5,187	....	6,494
European	5,149	....	5,239	....	4,912
	10,125		10,426		11,406

I may here mention that the exports of our home timber has so much increased as to exceed considerably our imports.

	1840.		1850.		1858.
Loads	844	....	10,827	....	15,800

It was after 1840 that our great forests began to be cut down, and the demand for pit-props and railway sleepers has added much to the value of our home timber.

Wheat.—The number of quarters of wheat imported was

1840.	1850.	1858.
14,841	27,003	31,446

Oats, Barley, &c.—While our exports of oats, &c. were in

1840.	1850.	1858.
45,675	48,566	76,158

thus showing that we export more than double the quantity of grain than we import. Besides the following quantities of meal, in bolls of 140 lbs:—

Meal:—

1840.	1850.	1858.
18,873	70,188	69,652 bolls.

Iron.—The imports of iron were as follows:—

1840.	1850.	1858.
4734	4300	9116 tons.

Cattle, &c.—The number of cattle exported by sea was in

1840.	1850.	1858.
6422	9940	5652

In the same year, 1858, there were sent by railway 13,674; so that last year the whole cattle sent from this quarter principally to the London market, was 19,326, besides dead meat amounting to 5226 tons. The number of sheep and lambs exported last year by sea and railway, was upwards of 15,000, and the value of the whole cattle, alive and dead, sent from this quarter, cannot be less than from £500,000 to £600,000 annually.

I may here mention that the whole imports and exports of the Scottish North-eastern Railway for the year ending 31st August 1858, were,

Imports.	Exports.
28,203	26,567 tons,

besides coal and live stock, which are mentioned above.

Granite.—The subject of our celebrated granite, in all its departments—quarrying, building, causewaying, and polishing—is to form the subject of a separate paper by Mr. Gibb, a gentleman in every way qualified to do it justice. I shall therefore merely mention the exports for

1840.	1850.	1858.
25,557	30,385	32,422 tons.

These were principally causeway-stones for London; and I may add that the average value laid down in London is about 20*s*. per ton, of which 6*s*. may be stated as freight, 2*s.* as cartage from the quarries to the harbour, and the remainder (12*s.*) as wages of quarrymen and rent of quarries.

Salmon.—The only other subject I have time to mention is our Salmon Trade; and I trust that some one connected with the fishing may be induced to give a paper upon it. It is one of deep interest and importance. I regret that I cannot give even a complete statement of the exports, as the Railway does not keep a separate return of the number of boxes sent by them. The harbour affords the following in barrel bulk of 112 lbs. each:—

1840.	1850.	1858.
3067	6295	581

This last year is far from being complete, owing to a large quantity having been sent by railway of which no return can be obtained. But still it is obvious that this valuable fish is deserting our coasts and rivers, as centuries ago we exported in some years a much larger quantity than we now export; and in 1816, which was a favourable year, no less than 15,000 boxes, containing each about 100 lbs., left the harbour. It was the opinion of the late Sir Walter Scott that our agricultural and commercial improvements would gradually tend to drive them from our shores.

On the Progress of Public Opinion with respect to the Evils produced by the Traffic in Intoxicating Drink, as at present regulated by Law. By the Rev. W. Caine, *A.M.*

He advocated the Permissive Bill, which proposed to give the power to suppress the traffic if two-thirds of the community were in its favour. Canvasses had been made in the various towns of England, Ireland, and Scotland, with the most favourable results to the object advocated. The lower classes manifested the greatest interest in this matter, and evidently showed their anxiety to be freed from the temptations by which they were surrounded. At the districts which have been canvassed, it has been found that the poor are in favour, while the rich oppose it. Various towns have been canvassed, such as—

Huddersfield	in favour,	387	Parliamentary Voters;	609	Municipal Voters.
Grimsby	do.	252	do.	500	do.
Carlisle	do.	222	do.	858	do.

The municipal electors, were they to do their duty, might have considerable power at the elections in using their influence in favour of the Permissive Bill. The liquor traffic has been brought before the public during the last few years in many ways—the Permissive Bill of the United Kingdom Alliance receiving great prominence; and the audiences have ever given their decided approval of the Bill: 2000 ministers in Britain have signed a document, deploring the traffic in intoxicating drinks, and recommending all clergymen to use all legitimate means to obtain the suppression of the traffic.

On the Effects of the recent Gold Discoveries. By J. Crawfurd, *F.R.S.*

On the Effects of the Influx of the Precious Metals which followed the Discovery of America. By J. Crawfurd, *F.R.S.*

The scope of Mr. Crawfurd's paper went to show that the depreciation in the value of the precious metals consequent on their influx after the discovery of the American mines, and the enhancement in the price of all the commodities they represented, so often insisted on by public writers, really never took place, any more than has the gold of California and Australia in our own times. He quoted, for this purpose, the prices of several articles which are even now the same as before the discovery of America.

On the Social and Economical Influence of the new Gold. By Henry Fawcett, *M.A., Trinity Hall, Cambridge.*

It is very important to arrive at some definite opinions on a subject which has been so much confused. The new gold has produced three series of effects.

1st. The quantity of the substance which has generally been adopted as the medium of exchange has been augmented.

2ndly. The new gold has influenced the wealth and the social condition of the countries in which it has been discovered.

3rdly. Great Britain has been affected by this change in the condition of one of her colonies.

When it was found in 1851 that Australia and California would annually supply nearly £30,000,000 of gold, or, in other words, at least four times as much as all the gold mines in the world had yielded before, it was supposed that gold would rapidly decline in value to the extent of at least 25 per cent. The best authorities now agree that this decline has not as yet occurred. I will in the first place state the reasons which justify this supposition, and then explain in what manner the increased gold has been absorbed and its value been maintained. An inductive proof of a change in the value of gold requires data which cannot be obtained; for a comparison of general prices during the last ten years will afford no proof. Thus wheat is cheaper now than then. The value of gold, compared with wheat, has risen; but how erroneous would it be thence to conclude that its general value had risen! Wheat has declined in price because it can be imported cheaply from other countries. On the other hand, the price of meat and dairy produce has of late much increased. This rise in price we know is partly due to the increasing wants of an advancing population, and especially to the increased consumption of a more numerous and better paid labouring class; but still we cannot say that the rise in the price of such produce has not been augmented by a fall in the general value of gold. Manifestly such comparisons avail nothing. The price of silver will afford the most important evidence. Silver and gold have been adopted as the general media of exchange, because they are liable to little change in their value. The value of these metals, like agricultural produce, is determined by the cost of obtaining them under the most unfavourable circumstances. Therefore their value is not altered, unless the current rate of profit in a country falls, and renders it profitable to work worse mines than those already worked; or, on the other hand, rises, and renders it no longer profitable to work these worse mines. Where commodities are employed in industrial occupations, the demand is variable; their value depends upon the demand; and this value constantly tends to obtain that position of stable equilibrium, when the supply equals the demand. But the quantity of gold and silver which is used for industrial purposes is very insignificant; and when a substance is used merely as a medium of exchange, the demand is always exactly equal to the supply, and the aggregate supply determining the value, and the value in a crossway regulating the supply, because the supply must give such a value as will cause the current rate of profit to be obtained in the worst mines. If, therefore, within the last ten years no new silver mines have been discovered, and the worse mines which were then worked are worked now, it affords strong evidence that nothing has occurred to affect the value of silver. As therefore the value of silver has remained stationary, if gold has declined in value 25 per cent., silver estimated in gold would have increased 25 per cent. in price. But it has not increased more than 2 per cent. This, I believe, affords the strongest evidence which can be obtained that the general value of gold has not yet declined. For some years up to 1840, our exports and imports had steadily increased. About that time the progress seemed to have ceased; for from 1840 to 1846, our exports remained at the stationary point of about £50,000,000 per annum. The fettered energy of the country seemed to have achieved its utmost. Free trade, and the repeal of the navigation laws, unloosed these fetters, and then the country started on a career of the most extraordinary progress. Our exports in nine years advanced from £50,000,000 to £115,000,000. In 1847, 475,000,000 pounds of cotton were imported; in 1856, more than 1000,000,000 pounds. This increased commerce stimulates the accumulation of capital, the wage-fund of the country is augmented, and wages, especially in the manufacturing districts, obtain a very decided rise. Free trade also cheapens many of the prime necessaries of life, and much more can therefore be spared for luxuries. No luxury is more prized by the poor than tea, and hence we find that while only 50,000,000 pounds of tea were imported in 1850, 86,000,000 pounds were imported in 1856. In Europe, during the last few years, there has been a great failure of the silk crop. China has been resorted to; and thus while only 1,700,000 pounds of silk were imported in 1850, more than 4,000,000 pounds were imported in each of the years 1854, 1855. The plodding industry of the Chinese enables them to supply this increased tea and silk; but surrounded with all the prejudices which have resulted from an isolation of 2000 years, we can induce them to take no useful commodities in return. They will be paid in silver, and we are thus obliged, in order to adjust the balance of trade, annually to export to the East £14,000,000 of silver. The silver coinage of France has to a great extent supplied this silver. £45,000,000 have been thus abstracted from her silver coinage in six years, from 1852–58. Gold has supplied its place. The absorption of so much gold in this way, has induced M. Chevalier, in his work on money, so admirably translated by Mr. Cobden, to describe France as a parachute, which has retarded the fall in the value of gold. France has supplied so much silver—

1st. Because of the large amount of silver coinage she formerly possessed; and

2ndly. Because, unlike us, she has a double standard.

Any slight variation in the fixed relative values of these two metals, will induce all payments to be made in one of these metals alone. Every extension of credit enables a certain amount of the circulating medium to be dispensed with; and it is probable that our vastly increased commerce and trade has required little, if any greater quantity of the circulating medium for all those transactions which may be described as wholesale; but, as I have before observed, a great increase of the national capital must have accompanied this commercial progress. The wage-fund is a component part of this capital. Wages are almost always paid in coin. This points to another way in which much of the new gold has been absorbed. The possibility of accounting for the absorption of the new supplies of gold, confirms the opinion that its value has not declined. But the fact that there has been no reduction, proves that gold would have greatly risen in value had not these supplies been forthcoming. The rise, too, would have been sudden, and therefore most serious. The conditions of every monied contract would be altered, the National Debt would be a more severe burden, and the extension of our commerce with the East would meet with the most difficult obstacle.

When feudal Europe ripened into commercial Europe, the gold of America was discovered; and now that free trade has inaugurated a new social and commercial era, the gold of Australia and California is ready at hand to aid the progress.

M. Chevalier asserts that henceforth the value of gold will rapidly decline at least 50 per cent. I regard this as a much too confident prophecy. The wage-fund of most countries is increasing, in some cases most rapidly. This will absorb a great deal of gold. Our commerce with the East is so anomalous, that prophecies seem to me to be useless. Every year there is a constantly greater quantity of Eastern produce required, and therefore this increased commerce will very soon absorb, instead of £14,000,000 of specie, £20,000,000, unless some great change in the habits of the Chinese induces them to consume more European commodities. On such a point who will hazard a prediction? Thus in a few years the East will absorb all the silver of the West. Shall we then be able to induce the Chinese to take gold as readily as they do now silver? There is another consideration which seems to me to be not sufficiently noticed. A change in the value of gold always generates a counteracting force, whose tendency is to restore the metal to its former value. Thus, suppose the supplies of gold continue to be the same as they are now, and that after a certain time gold declines in value. Gold-digging is not, I may say cannot be, more profitable than other employments. Directly a decline in the value of gold takes place, gold-digging will to many become less profitable than other labour. They will therefore cease to dig; this will diminish the aggregate supply of gold, and this diminution will tend to restore its value. I will now proceed to explain in what way the gold discoveries have assisted the advance of Australia. Production has three requisites:—

1st. Appropriate natural agents.

2ndly. Labour to develope the resources of nature.

3rdly. This labour must be sustained by the results of previous labour, in other words, by capital.

Long previous to 1848 the great natural resources of Australia were known, her vast tracts of fertile land had been explored, and her climate had been pronounced healthy. There was an overplus of labour in this country, and there was also much capital which would have been at once accumulated had an eligible investment presented itself. Little labour and capital were, however, applied in Australia, and her advance was slow. We know the discovery of gold changed all this; let us, then, seek the secret of the change. Previous to the gold discoveries, the chief field for the investment of capital was agriculture. In a young country farming operations meet with many obstacles. The stock and implements are expensive, no steady supply of labour can be ensured; and without the investment of a great deal of capital in roads, and other such works, produce can with difficulty be brought to market, and when brought, the demand is uncertain. The same remarks apply to manufactures, and also to general mining operations; for lead, copper, and iron mines require most expensive machinery, and a large cooperation of labour. This explains the usual slow progress of colonies, even when they offer the greatest industrial advantages. But as soon as it was heard that the gold was spread over a large breadth of the Australian continent, thousands flocked to share the spoil. They only took the simplest tools, they needed no capital, but just sufficient food to support them while labouring; and each one felt that he could work independently, and risk nothing more than his labour and his passage-money. Australia having thus suddenly obtained an abundance of manual labour, possessed two of the requisites of production; the third, capital, was quickly supplied to her. The savings of the gold-diggers formed a large capital, and English capital now flowed in even too broad a stream, to supply the wants of this labouring population. Australia for a time suffered much inconvenience, because gold-digging absorbed all her labour; not that more was earned in this pursuit than in others, but there is a magic spell in the name of gold. Gold-digging has the excitement of a lottery, and the chances of a lottery are always estimated at more than their true value. After a time, other pursuits absorbed a due proportion of labour, and thus Australia possessed every attribute of industrial success, and her future prosperity was established.

About 1848, England was suffering from those ills which political economy attributes to over-population. Wages were becoming lower, and increasing population necessarily made food more expensive. Ireland had famine, and we had most deplorable distress. I have mentioned that the discovery of gold acted more powerfully than any other circumstance to induce a large emigration from Great Britain. Any decrease in the number of those who seek employment must cause a rise of wages, but emigration from a country like our own, effects even a more important advantage. I have before observed that the price of agricultural produce at any time must be such as will enable the least fertile land which is cultivated, to return the ordinary rate of profit. If, therefore, the wants of an advancing population cause more land to be brought into cultivation, the food which is thus raised involves a greater expenditure of labour and capital than that which was before produced, and thus as population advances, food becomes dearer. In a thickly peopled country, there are two obstacles to the material prosperity of the poor:—

1st. The number of those competing for employment reduces wages.

2ndly. Food rises in value as it becomes necessary to strain the resources of the fertile land.

Emigration, therefore, has increased not only the monied wages, but the real wages of our labourers. In some of our colonies, such as Canada, so little of the fertile land has been cultivated, that for some time the greater the immigration is to those parts, the more abundant will be the supply of cheap food which will be exported to this country. Emigration, therefore, as it were, adds a tract of fertile land to our own soil. Again, wages are remunerated from capital. The amount saved, or, in other words, the capital which is accumulated, is regulated by the returns which this capital will obtain. If population is stationary, and capital increases, wages will rise, and profits will fall; if, on the other hand, capital is stationary, and population increases, the rate of profit will fall. Can we affirm anything with certainty about the tendency of profits, when capital and population both increase? Any augmentation in the numbers of the labourers must exercise an influence to reduce wages, and therefore to raise profits; but there is another consideration. In a thickly peopled country like Great Britain, the returns of the Registrar-General plainly indicate that the rate of increase of population amongst the labouring class is determined by the expense of living, for the number of marriages invariably increases or decreases as food is cheap or dear. Such being the case, there is always a portion of the labouring class whose wages are very little more than sufficient to provide them with the necessaries of life. Such wages I will describe as minimum wages. Since we have seen that an increasing population must always have a tendency to make food dearer, these minimum wages must, from this cause, have a constant tendency to rise. This acts as a counteracting force to reduce profits. We can now attribute another important influence to emigration. It raises wages by reducing the number of the labouring class; but since, as I have said, it adds a tract of fertile land to our own soil, it cheapens food, and since cheap food prevents a reduction in the rate of profit, there will be a greater inducement to save. The capital of the country will from this cause become augmented, and there will be therefore a larger fund to be distributed amongst the wage-receiving population. When emigration is thus considered, its vast social and economical importance can be understood. Mr. J. S. Mill, who, more than any living person, has systematically thought upon the modes to ameliorate the condition of the poor, emphatically insists that it is necessary to make a great alteration in the condition of, at least, one generation, to lift one generation, as it were, into a different stage of material comfort. He attributes little good to slight improvements in the material prosperity of the poor, because, unless accompanied with a change in their social habits, the advantage is sure, as it were, to create its own destruction, by encouraging an increase of population. It seems to me that there can be no agency so powerful as emigration to effect a great change in the material condition of the poor. I therefore regard the discovery of gold to be of the utmost social value to England; for it has been so potent an agent to induce emigration, that it has caused Australia in ten years to advance from a settlement and become a nation, with all the industrial advantages of the oldest and most thriving commercial community.

On Popular Investments. *By* Sir John S. Forbes, *Bart., of Fettercairn.*

The Savings' Banks have produced a vast amount of benefit to the industrial classes. In eleven years after 1817, when they became general, about thirteen millions was received, and the sum deposited in them in 1857 exceeded thirty-five millions for the British Islands. The largest number of depositors above 250,000, held sums between £1 and £5, the total number of depositors being 1,341,752.

The average per head—			£ s. d.
In England,	£26,	or for the population	1 15 0
In Scotland,	16 4*s.*	ditto	0 13 5
In Ireland,	30 0	ditto	0 5 3

The average of deposits in Scotland to the population is small as compared with England; but, besides the poverty of the country, this may be accounted for, without any disparagement to its admitted economy, by the fact that the branches of the common banks now established in every large village afford great facilities for investment, and it probably in part proceeds from the intelligence of the people, who seek for other sources of return for their capital.

It is remarked that the class of depositors is not generally what might be expected. In Scotland, domestic servants are generally the most numerous class, with artisans, mechanics, and hand-loom weavers, while scarcely any of the mill-workers deposit. In Glasgow and Edinburgh, and Aberdeen, the females exceed the males in number. The rural classes do not largely avail themselves of these institutions as compared with the inhabitants of the towns. In Perthshire there are only £554 as against £7091. In Aberdeen the average to each depositor is a little above £12. In 1847, the deposits in that bank amounted to £88,000, while in November last it had risen to £191,731, in 22,744 accounts.

Though Assurance Offices were originally arranged for a class above the industrial, the small premiums which their schemes require are perfectly adapted to the smallest incomes. For example, the following satisfactory arrangements may be made for the future at many respectable offices, any one of the objects being secured by beginning at the age of twenty to pay 1*s.* per week. Of course 2*s.* per week will secure double those sums in reversion, and 6*d.* per week one-half of them.

1. £150 will be paid to his family on his death.
2. 400 to himself, if he survives the age of 65.
3. 270 to do. do. 60.
4. 130 to himself at 65, or his family, if he dies sooner.
5. 40 to £50 per annum, if he survives 65.
6. 20 do. and £75 to family, if he dies sooner.

How many young men at that age are wasting, nay, worse than wasting, spending, to the injury of their health, habits and reputation, 2*s.* 6*d.* per week, which would secure to them £1000 at the age of sixty-five, or £115 per annum thereafter during life, if the payment is persevered in with that object!

A similar scheme of deferred annuities is now proposed by the Government, to be effected at any of the National Security Savings' Banks, which, upon the payment of a sum of £2 2*s.* 2*d.* at the age of twenty, will secure a sum of £1 per annum after the age of sixty-five, or be returned if he does not reach that age. If not made returnable, the annuity may be secured by paying 18*s.* 6*d.* down. Another pound a year may be insured by paying 19*s.* 6*d.* next year, and so on.

On the Agricultural Statistics of the County of Aberdeen. *By* Arthur Harvey.

After describing the divisions, appearance, soil, climate, and extent of the county, with its population and rental, exclusive of the towns, noticing the methods of agriculture practised at the end of last century, when Sir John Sinclair completed his statistical inquiry, and in 1811, when, under the direction of the Board of Agriculture, Dr. Skene Keith completed his elaborate work, as well as at the present period, the author proceeded to show that at the end of last century the capital in stock and crop amounted to £1,212,821 15*s.*, or equal to £5 2*s.* 1*d.* per acre, with an area under cultivation of 238,741 acres; that in 1811 the aggregate capital in stock and crop had reached £2,469,500, or equal to £6 6*s.* 8¼*d.* per acre, with an area under cultivation of 389,556$\frac{1}{18}$ acres; and in 1858, that the aggregate capital in stock, crop, &c., amounted to £4,542,269 4*s.* 10*d.*, or equal to a gross produce per acre of £6 10*s.* 8*d.*, with an area under cultivation of 488,183½ acres. Accompanied by the annexed Tables, the following facts were brought out:—

	£	*s.*	*d.*		£	*s.*	*d.*
That since 1798 the rental of Aberdeenshire has increased from	133,630	0	0	to	540,000	0	0
The Grain crop from	486,745	0	0	to	1,175,840	6	1
The Green crop from	31,200	0	0	to	652,654	16	3
The Grass crop from	173,387	0	0	to	510,343	2	6
Total	£691,332	0	0	to	£2,338,838	4	10

The live stock has increased from £521,489 15*s.* to £2,203,431, but, from the rise in the rent of land, and the enormous expenses attaching to the prosecution of agriculture, the gross produce per acre, under deduction of expenses, &c., only shows a net return of 15*s.* 6½*d.* sterling to the farmer. And as a proof of the extent of the cattle-trade from the county, statistics were given, showing that the average number of "beasts" killed per week in the Aberdeen district was 700, and of sheep 250, with, in 1858, the shipments by steam of cattle 5652, sheep 6622, pigs 1702, and by rail 13,674 cattle, with 5226 tons of dead meat.

Estimate of Annual Produce and Sales, Capital, Expenses, and Returns.

Annual Produce of Soil—Grain Crop	£1,175,840	6	1				
„ Green Crop	652,654	16	3				
„ Grass and Pasture	510,343	2	6				
					£2,338,838	4	10

Annual Produce of Stock sold:—

34,172 Cattle (7 per 100 Ar. Ac.) at £18	£615,096	0	0
26,423 Sheep at 26*s.*	34,349	18	0
Carried forward	£649,445	18	0

BLE of Acreage and Values of the several Agricultural Products, per Sir John Sinclair's estimate in 1798, that of Dr. Skene Keith in 1811, and at the present time in the County of Aberdeen.

		Estimated Acres. Sir J. Sinclair.	Value, per Imperial Acre.	Total.	Estimated Acres. Dr. Skene Keith.	Value, per Imperial Acre.	Total.	Acres, Present Time, per Agricultural Statistics.	Imperial Acre, Agricultural Statistics.	Value, per Imperial Acre.	Total.
		Acres.	£ s. d.	£ s. d.	Acres.	£ s. d.	£	Acres.	Bush. Peck.	£ s. d.	£ s. d.
GRAIN CROP, &c.	Wheat	126	6 3 0	770 0 0	515 1/16	9 18 0	5,100	8,962	24 1	6 7 9	57,274 19 8
	Barley	43,843	2 19 8	130,875 0 0	467 7/8	6 1 8	2,800	9,534	32 0	7 10 8	71,823 14 10
	Bere				129,521 7/8	5 15 6	170,500	6,121	34 3	7 18 6	48,523 2 0
	Oats	180,900	1 18 $2\frac{1}{2}$	345,600 0 0	150,875 5/8	4 16 10	730,600	165,275	33 0	5 18 11	982,869 15 4
	Beans	63	2 7 $6\frac{1}{2}$	1,500 0 0	1,934 6/8	3 3 0	6,100	366¼	30 2	6 5 0	2,303 16 3
	Pease							255	30 2	6 3 7	1,575 13 0
	Rye	....	......	....	50 2/8	6 0 0	300	687½	24 0	5 14 0	3,919 5 0
	Flax	631	12 13 9	8,000 0 0	251 2/8	8 0 0	2,000	37½	....	12 10 0	450 0 0
	Turnip Seed	....	......	....	....	....	....	355	....	20 0 0	7,100 0 0
		226,131	......	486,745 0 0	183,616 1/16	.. ..	917,400	191,593¼	....	....	1,175,840 6 1
GREEN CROP.	Tares	....	......	....	....	....	....	2,102¼	....	4 0 0	8,409 0 0
	Turnips	2,522	4 15 2	12,000 10 0	28,893 7/8	5 15 0	166,100	82,316¼	....	7 0 0	576,213 15 0
	Potatoes	5,044	3 16 2	19,200 0 0	5,276 3/8	9 17 1	52,000	7,090	2 t. 9 cwt.	9 5 0	65,082 10 0
	Mangold	....	......	....	....	....	....	17¾	14 t.	4 10 0	79 17 6
	Carrots	....	......	....	....	....	....	56	....	15 0 0	840 0 0
	Cabbage	....	......	....	....	....	....	104¼	....	10 0 0	1,042 10 0
	Rape and other Crops	....	......	....	....	....	....	23¼	....	2 10 0	58 2 6
	Summer Fallow	....	......	....	....	....	....	743¼	....	4 5 0	929 1 3
		7,566	......	31,200 0 0	34,170 2/8	....	218,100	92,453	....	....	652,654 16 3
GRASS.	Grass and Pasture under Rotation	5,044	......	15,000 0 0	171,768 6/8		314,000	204,137¼	....	2 10 0	510,343 2 6
	Pasture estimated for Cattle, Horses, Sheep, &c.	....	......	158,387 0 0							
		5,044	......	173,387 0 0	171,768 6/8	....	314,000	204,137¼	....	....	510,343 2 6
	Grain	226,131	......	486,745 0 0	183,616¼	....	917,400	191,593¼	....	....	1,175,840 6 1
	Green Crop	7,566	......	31,200 0 0	34,170 2/8	....	218,100	92,453	....	....	652,654 16 3
	Grass and Pasture	5,044	......	173,387 0 0	171,768 6/8	....	314,000	204,137¼	....	....	510,343 2 6
		238,741		691,332 0 0	389,550 1/16	....	1,449,500	488,183½	....	....	2,338,838 4 10
	Add, Live Stock	....	......	521,489 15 0	....	....	1,020,000		....	....	2,203,431 0 0
				1,212,821 15 0			2,469,500				4,542,269 4 10

TABLE of the Numbers of Agricultural Live Stock, with their respective Values, by Sir John Sinclair's Report in 1798, that of Dr. Skene Keith in 1811, and at the present time in the County of Aberdeen.

Description of Stock. 1798.	Number.	Rate.	Value of each Description.	Description of Stock. 1811.	Number.	Rate.	Value of each Description.	Description of Stock. 1858.	Num. per Agricultural Statistics.	Rate.	Value of each Description.
		£ s. d.	£ s. d.			£ s. d.	£			£ s. d.	£
Horses	21,448	6 0 0	128,688 0 0	Horses	8,600	20 0 0	172,000	Horses	23,420	20 0 0	468,400
Cattle	89,074	3 10 0	311,759 0 0	Cows	28,000	7 0 0	196,000	Cows	36,864	12 0 0	442,368
Sheep	164,171	0 5 0	41,042 15 0	Calves reared	22,000	2 0 0	44,000	Cattle, 1, 2, 3 years	76,412	14 0 0	1,069,768
Hogs, Deer, Goats, Rabbits, Poultry, Pigeons	....	....	40,000 0 0	Year Olds	20,000	3 15 0	75,000	Calves	31,808	3 10 0	111,328
				Two-year Olds	19,000	7 10 0	142,500	Sheep—Breeding	33,001	0 14 0	85,041
				Three and above	21,000	12 10 0	262,500	,, Others	46,949	1 2 0	
				Sheep	100,000	1 0 0	100,000	,, Lambs	25,741	0 8 0	
				Hogs, Goats	....	....	....	Pigs	10,184	1 10 0	15,276
				Bees, Poultry, &c.	....	....	28,000	Poultry	150,000	0 1 6	11,250
			521,489 15 0				1,200,000				2,203,431

RECAPITULATION.

			£ s. d.				£				£ s. d.
Horses, 1798	21,448	....	128,688 0 0	Cattle, 1798	89,074	....	311,759	Sheep, 1798	164,171	....	41,042 15 0
,, 1811	8,600	....	172,000 0 0	,, 1811	110,000	....	720,000	,, 1811	100,000	....	100,000 0 0
,, 1858	23,420	....	468,400 0 0	,, 1858	145,084	....	1,623,464	,, 1858	105,691	....	85,041 0 0

Pigs, Poultry, &c.,	1798	£40,000
,, ,,	1811	28,000
,, ,,	1858	26,526

Brought forward		£649,445 18 0	
1,00 Horses........................ at £30		30,000 0 0	
Dairy Produce, 36,864 Cows...... at £4		147,456 0 0	
Pigs £7250; Poultry, £9000; Wool, £7860		24,110 0 0	
			851,011 18 0
Total Produce, annually			£3,189,849 2 10
£6 10*s.* 8*d.* per Arable Acre.			

For the fuller ascertaining of Capital invested, say:—

Annual Produce of Grain, Grass, and Green Crop		£2,338,838 4 10	
Total Live Stock		2,203,431 0 0	
		£4,542,269 4 10	
Add—Implements at 20*s.* House Furniture 10*s.* per acre.. 30*s.*		732,275 5 0	
		£5,274,544 9 10	
Under deduction of one year's Rent	£488,183 10 0		
Rates..................................	40,275 3 0		
2nd year's Grass not payable......	255,171 11 3		
Harvesting Crop......................	98,191 8 0		
		881,821 12 3	
and 2619 Horses, not Agricultural, at £	20 0 0	52,380 0 0 at £	
Probable Capital invested		£4,340,342 17 0	

Expense of Production, &c.

1. Keep of 76,412 Cattle—1, 2, and 3 years' old, average of £7	£534,880 0 0	
" 36,864 Cows, at £7	258,048 0 0	
" 31,808 Calves, at £3.........................	95,424 0 0	
		888,352 0 0
2. Keep of 20,801 Agricultural Horses on Grass at 50*s.*	£52,002 10 0	
" 16,836 for Hay, at £3; 3965 at £2.........	58,338 0 0	
" 16,836 for Grain, at £8; 3965 at £3	146,583 0 0	
		256,923 10 0
3. Keep of Sheep, 105,691 Sheep on arable ground, at 3*s.*		15,853 13 0
" Pigs, Poultry, &c.		7,000 0 0
4. Seed of Grain Crop..................................	£129,357 6 5	
" Green Crop..................................	25,099 19 2	
" Grass and Clover Seeds.....................	45,918 4 0	
		200,375 9 7
5. Rent, at 20*s.* per Imperial Acre	£488,183 10 0	
6. Rates, &c. 1*s.* 6*d.*..	40,275 3 0	
		528,458 13 0
7. Money—Wages of Servants, Day Labourers, and Harvest hands, 11*s.* 10*d.* per Imperial Acre. Food for Servants and Harvest hands at 5*s.* 2*d.*... 17*s.*		414,955 19 6
8. Extraneous Manure:—		
8,500 tons Lime, at 18*s.*	£7,650 0 0	
10,000 tons Bones, of all sorts, dissolved, &c. £7	70,000 0 0	
8,000 tons Guano, at £14	112,000 0 0	
Other Manures (Towns and Villages), &c.	6,000 0 0	
		195,650 0 0
9. Extraneous Food for Stock, Oilcake, &c.		15,000 0 0
10. Repairs to and keeping up of Implements, Machines and Harness, House Furniture, &c., 2½*d.* per cent.		50,276 0 0
11. Expenses of Men and Horses on Turnpike and Statute Labour Roads	£23,343 0 0	
12. Expenses of Farmers to Markets, Custom, 26 Markets each, 7348 Occupants, at 3*s.*..........	28,650 0 0	
		52,000 0 0

13. Fuel, Coals, &c.				27,121	0	0
14. Deterioration on 10,694 Horses employed in Agriculture, at 30*s.* each	£16,041	0	0			
Loss on Live Stock by death 1 per cent	20,282	2	0			
				36,323	2	0
				£2,688,289	7	1
15. Allowance for oversight, Farmers' wives and themselves, nothing being charged for them, 5*s.* per acre	£122,045	17	6			
				122,045	17	6
Total Expenditure				£2,810,335	4	7
16. Interest on Capital, £4,340,342 17*s.* 7*d.*, at 5 per cent. per annum				217,017	2	10
				£3,027,352	7	5
Balance to provide for Extras and Accumulation				162,496	15	5
				£3,189,849	2	10

Gross Produce, per Acre	£6	10	8
Expenses, per Acre	5	15	1½
Nett—Return, per Acre	£0	15	6½

NOTE.—Straw not charged, because returned in manure, £286,045 19*s.* 4*d.*

On some Results of the Society of Arts' Examinations. *By* J. POPE HENNESSY, *M.P., F.G.S.*

The author divided the subject into scholastic examinations and institutional examinations. The former include such examinations as those so successfully undertaken by the Universities of Oxford and Cambridge, for the middle classes, and the latter were those conducted by the Society of Arts for the artisan or working class. There was no competition whatever between these two systems. They formed, in fact, one comprehensive scheme, each system supplying the wants of its own particular class. The advantages of the examination of the Society of Arts had already been experienced in—

Aberdeen.
Ashbourne.
Ashbourne.
Ashford.
Bacup.
Banbury.
Basingstoke.
Bedford.
Belfast.
Berkhampstead.
Birmingham.
Blackburn.
Blandford.
Bradford, Yorks.
Brighton.
Bristol.
Bucks. and Berks. Lecturers' Association.
Bury.
Canterbury.
Carlisle.
Carshalton.
Chelmsford.
Dover.
Frome.
Glasgow.
Greenwich.
Halifax.
Hanley "Potteries."
Hartlepool.
Hitchin.
Holbeck.
Holmfirth.
Ipswich.
Leeds.
Leicester.
Lewes.
Liverpool.
Lockwood.
London.
Longton.
Louth.
Lymington.
Lynn (King's).
Macclesfield.
Manchester, M.I.
Middlesborough.
Neath.
Newcastle-on-Tyne.
Northowram.
Paisley.
Pembroke Dock.
Portsmouth.
Richmond (Surrey).
Salford.
Salisbury.
Selby.
Sheerness.
Sheffield.
Skipton.
Slough.
Wakefield.
Warminster.
Waterford.
Wigan.
Windsor.
Wirksworth.
York.

Such a large and widely-distributed list of local Boards was an evidence of unequivocal success. On looking to the results of the final examination which had taken place some months ago, and comparing these results with the operations of the preceding year, it will be seen that the number of candidates has very much increased. The following Table exhibits this comparative position of the results for 1858 and 1859:—

No. of Candidates Examined at the Final Examination.		No. of Candidates who passed Final Examination.		No. of Papers worked at Final Examination.		No. of 1st Class Certificates awarded.		No. of 2nd Class Certificates awarded.	
1858.	1859.	1858.	1859.	1858.	1859.	1858.	1859.	1858.	1859.
288	480	197	368	516	166	53	78	132	154

No. of 3rd Class Certificates awarded.		No. of Prizes awarded to Candidates.		No. of Prizes awarded to Local Boards.		No. of Prizes awarded to Institutions.		No. of Unsuccessful Candidates.	
1858.	1859.	1858.	1859.	1858.	1859.	1858.	1859.	1858.	1859.
176	308	25	28	2	4	16	7	79	112

The ages of these Candidates varied from 16 to 47. The following Table has been compiled from the return papers of 525 candidates, 480 of whom underwent the final examination:—

Age.	No. of Candidates.	Age.	No. of Candidates.	Age.	No. of Candidates.	Age.	No. of Candidates.
16	52	23	23	30	9	37	2
17	68	24	16	31	6	38	1
18	77	25	21	32	5	39	3
19	64	26	11	33	6	41	1
20	54	27	4	34	1	43	1
21	44	28	6	35	1	44	1
22	36	29	8	36	2	47	2

The return paper also exhibited the number of years the various candidates had spent at school. It appeared from this important portion of the returns that a prolonged period of school life was by no means the most satisfactory indication of educational progress. Many candidates had not only obtained first-class certificates, but had even carried away prizes, whose school attendance was far below the average; and, on the whole, it would appear that the instruction afforded by Mechanics' Institutes, and other educational agencies, subsequent to the school period, was equally valuable, if not more so, than that usually given during the last few years of school life. If we could get young workmen to avail themselves of this secondary education, there could be little doubt but that a short period of elementary school attendance would not be so serious an evil as was generally supposed. Even with the present imperfect condition of Mechanics' Institutes, the results of the Society of Arts' Examination supplied ample evidence to prove, at least, this important fact, that we should not attempt to estimate the educational position of the working-classes merely by looking to the census returns, or to the official reports on school attendance. Hitherto we had no opportunity of ascertaining what effect Mechanics' Institutes produced. Although our present information was not as extensive as could be wished, it was sufficient to indicate the great value of institutional instruction.

On Decimal Coinage. *By* R. L. Johnson.

On some Questions relating to the Incidence of Taxation. By J. Pope Hennessy, *M.P., F.G.S.*

Statistical Account of the Whale and Seal Fisheries of Greenland and Davis Straits, carried on by Vessels from Peterhead, N.B., from 1788 *to* 1858, *a period of* 71 *years. By* Thomas Lawrance.

The Greenland Whale Fishery began in 1788; a vessel called the 'Robert,' of 169 tons register, sailed from the port in the spring of that year, and continued its solitary voyages until 1801, when it was sold. The 'Hope,' of 240 tons, followed, and was joined by the 'Enterprise,' of 299 tons, in 1804, and by a vessel called the 'Active,' of 308 tons, in 1810. They continued to increase from year to year; and in 1821 the whale fishery of Davis Straits was attempted, as well as that of Greenland. In that year the combined fleets consisted of sixteen vessels, of an aggregate tonnage of 4584 tons. The Fishings appear to class themselves into three periods, viz. the whale period of Greenland, from 1788 to 1820; the whale period of Davis Straits, from 1821 to 1840; and the whale and seal period of both fisheries, from 1841 to 1858, viz.:—

		Years.	Voyages.	Tuns of Oil.	Tuns per Voyage.
Greenland	1788–1820	33	116	9,060	=77
Davis Straits	1821–1840	20	159	13,015	=81
Greenland	1821–1840	20	88	4,467	=51
Greenland and Davis Straits	1841–1858	18	337	18,040	=53

The total number of complete voyages was 700, and the gross quantity of oil brought home 44,582 imperial tuns, which shows an average of 64 tuns a voyage.

In the year 1838 the fleet numbered ten ships, and from that time to 1851 the number did not exceed thirteen any season; but in 1851 they rose to twenty-two, in 1853 to twenty-seven, and in 1857 to thirty-one, the largest number which ever sailed from the port. During the period from 1838, the Seal Fishery of Greenland has attracted much attention, and has been sedulously pursued. The largest number of seals caught by the crew of one vessel previous to 1844 was 6130; but in that year the 'Plover' brought home 12,300 seal skins, and 135 tuns of oil; and in 1850 the 'Victor' captured 16,135 seals, which produced 185 tuns of oil. The fishing continued with varied success until 1855, in which year the large number of 131,049 seals were taken: since that season, the fishing has fallen off, and attention has been directed to the capture of whales at Cumberland and Davis Straits. Vessels from Peterhead, Aberdeen, and the United States of America have for some seasons gone out and wintered at Cumberland Straits, where whales are caught in autumn, the latter end of spring, and during summer; but the risk and expenses attending these voyages, compared with the produce caught, has rendered them as yet unremunerative. The steam-tug 'Jackall' accompanied the ship 'Traveller' to Cumberland Straits in 1857, to assist in towing the boats and dead whales to the vessel: both have since been lost there. The same year the iron screw steamer 'Inuit' entered the trade. The owners were sanguine that the application of steam at those fisheries would prove as serviceable and profitable as it had been in other trades, but the experiment did not come up to expectations; the trial, however, was short; the vessel was crushed in the ice at the seal fishing of Greenland this spring. The walrus fishing off the coast of Spitzbergen was tried, but failed for want of sufficient success. The whale fishing off the coast of Nova Zembla was attempted last year; but, though unfruitful, another and more vigorous trial is necessary before it can be said that whales are to be found, or not, off the shores of that island.

The total number of vessels engaged from first to last was 58, of the gross tonnage of 15,617 tons register, averaging 269 tons each. 504 voyages were made to Greenland, and 214 to Davis Straits, but only 700 voyages homewards, as eighteen vessels were lost at the fisheries.

The losses, sales, and number of vessels now engaged at the fisheries are as follows:—

4 vessels lost at Greeenland	1,241	tons per register.
13 vessels lost at Davis Straits	4,111	"
1 vessel lost at Iceland	308	"
2 vessels lost trading to Baltic	604	"
1 vessel lost at Moray Frith	157	"
1 vessel lost at Archangel	289	"
1 vessel lost at North Sea	132	"
7 vessels sold	1,450	"
28 vessels engaged at the fisheries	7,325	"
58	15,617	

Assuming the value of these vessels at £20 per ton, including provisions and wages, the total first cost would have been £312,340; but as they decline in value as they increase in age, the average during employment may be calculated at £15 per ton for those going to Greenland, and £17 for those in the Davis Straits Fishery. The losses at the former would therefore amount to £18,915, and at the latter £69,887. Comparing the losses at Greenland with those at Davis Straits, out of 504 voyages to the former 4 vessels were wrecked, and out of 214 to the latter 14 were wrecked, which demonstrates the risk at Davis Straits to be eight times greater than at Greenland; at the one country the loss is under 1 per cent., and at the other about 6½ per cent. It may be observed, that the class of vessels which has gone from Peterhead to Greenland of late years has been superior to those of some other ports, and consequently the casualties have been less in proportion amongst Peterhead ships. The rates of premium and policy of insurance to Greenland is £3 7*s*. 6*d*. per cent., and to Davis Straits £6 10*s*. 6*d*. per cent: formerly the rates were higher. Of all places frequented at these fisheries, the danger of shipwreck is greatest at Melville Bay, on the east side of Davis Straits. In the year 1830, one French and nineteen British vessels were lost in that bay; the loss of life, however, is very small, as the men can instantly get upon the ice and walk to other vessels which may have accompanied them.

The total importations from these fisheries for the 71 years has been, 1,121,685 seal skins, 3797 whales, producing 44,582 tuns of oil, and 1731 tons of whalebone, and of the approximate value of £2,323,380 sterling. The value of produce has changed very much from time to time; oil has been sold as low as £20 and as high as £54 per tun. Whalebone at one period was nearly valueless, and of late it has been sold in the London market at £580 per ton. Seal skins twenty years ago sold at 1*s*. to 1*s*. 6*d*. per skin, and they are now realising 3*s*. 9*d*. to 8*s*. 6*d*. per skin. In the early years of the fishing the vessels sailed in the end of March and beginning of April, but now they take their departure in the middle and end of February, returning in May, June, July, and August from Greenland, and in September, October, and November from Davis Straits. There is no record of the loss of life from accidents and disease, but the per-centage, if ascertainable, would no doubt be found to be small; the crews on their return from the icy seas always look healthy and strong.

On the Trade and Commerce of India. *By* J. T. Mackenzie.

The paper gave a view of the exports and imports of bullion and merchandise for twenty-five years, ending in 1858. The value of exports from British India amounted, in the five years from 1833–38, to £10,300,000 annually, while, for the five years from 1853–58, the amount annually was £22,810,755. Imports of merchandise, exclusive of treasure, averaged £4,717,278 yearly in the first period of the same series, and £13,457,015 yearly for the last. The total bullion imported into India for the twenty-five years was £110,329,428. The number of vessels entered into India from foreign ports in 1858 was 4309—increase £1,686,558. The largest item of merchandise imported into India consisted of cotton, twist, yarn, and piece goods, and amounted in 1858 to £4,695,400, of which £4,608,655 were supplied by the United Kingdom. The writer next alluded to the importance of the extension of this great market to every class at home; and the obvious means by which this great object is to be attained are, on the one hand, by increasing the producing power of India, and by enabling her to dispose of a large quantity of her own productions, and, on the other, by our manufacturers studying, more than they do at present, the habits of the people in the manufacture of articles best suited to their real wants, tastes, and fancies. The total value of merchandise exported from British India in 1858 was £27,453,692, of which £9,106,635 was for opium, none of which is entered for British consumption. Deducting this, the exports still exceeded £18,000,000, of which more than £10,500,000 came to the United Kingdom. The largest item of Indian exports, after opium, is raw cotton, which in 1858 amounted to £4,301,769, of which £3,296,698 came to the United Kingdom, and this is about £1,500,000 below the value of the manufactured cotton we sent out to her. He pointed to the importance that would attach to organized efforts made to promote the consumption of Indian produce, and thereby to stimulate her productive power. He next said the whole system of banking in India requires to be changed. The means of transport and irrigation were also noticed asgreatly needed and greatly important. It should be clearly understood, however, that, for the real extension of great commercial intercourse with India, it is no part of the duty of Government to aid, either directly or indirectly, by pecuniary grants, gifts of land, or guarantees of interest, any industrial or commercial undertaking of the country.

On the Statistics of the Trade and Progress of the Colony of Victoria. *By the* Hon. THOMAS M'COMBIE.

Before entering upon the subject matter of this paper, I may be permitted to state that I have confined myself entirely to the bare statistics of the subject, and leave the members to draw such deductions as they may think fit. Victoria has many claims on the people of this country in being the greatest instance of successful colonization in the history of the world; in being called after the greatest and most popular sovereign that ever ruled the British dominions; and in having, after an existence of twenty years, productions amounting to £20,000,000.

The colony of Victoria contains within its area about 54,000 square miles. Its boundaries are Bass's Straits to the south and east; the colony of South Australia, near the line of 141° of longitude to the east; and the colony of New South Wales to the north and north-east by a straight line drawn from Cape Horn to the nearest point of the River Murray, and thence by the course of that river to the eastern boundary of the colony of South Australia. This large tract of fine land was settled in 1836 by adventurers from New South Wales and Van Diemen's Land, and was said to contain 7000 aborigines, who have nearly all died out, only from 300 to 400 remaining. The commercial relations of the new territory were confined for some time to the intercourse between the new colonies and the neighbouring settlements on the Australian coast. The Customs revenue for the last quarter of 1840 was £1597; for the first quarter of 1841 it was £5609. The total of the ordinary revenue for the last quarter of 1840 was £3319; for the first quarter of 1841 it was £10,490. In April 1837, the population of the colony was but 500, and the stock consisted of but 14,000 sheep, 2500 head of cattle, and 150 horses. In 1841 there was a census taken, and the following was the result:—Population of Melbourne, 4479; of county of Bourke, 3241; of the district of Western Port, 1391; of Geelong, 454; of county of Grant, 336; of Portland, 597; of the county of Normanby, 1260: making a total of 11,728. Houses: In Melbourne, 769; county of Bourke, 432; Western Port, 110; Geelong, 81; county of Portland, 100: total, 1559.

Condition of the people.—Convicts in the employment of the Government in Melbourne, 64; in the county of Bourke, 34; Western Port, 5; Geelong, 20; Grant, 17; Portland, 2; county of Portland, 4: total, 146. In private assignment:—in Melbourne, 10; county of Bourke, 70; Western Port, 122; Geelong, 6; Portland, 23: total, 213, making a gross total of convicts in the districts 369, and 2 female convicts, or 371 in all. Of the male free population, 215 were born in the colonies; 6500 arrived free; 104 were emancipated convicts; and 124 ticket-of-leave holders. Of the free female population, there were 341 born in the colony; 2908 arrived free; 104 were emancipated; and 2 held tickets-of-leave.

Station in life.—Of those who can be ranked as employers and non-labourers, there were 1767; and of labourers 8926.

In March 1846, another census of the portion of the Australian territory which now forms Victoria was taken, and it was found to be 32,876. The following are the details:—Population, Melbourne, Gipp Ward, males 1758; females 1602—total 3360. Bourke Ward, males 976; females 929—total 1905. Lonsdale Ward, males 1481; females 1176—total 2657. La Trolee Ward, males 1557; females 1495—total 3052. County of Bourke, males 3688; females 2688. Gipp's Land, males 612; females 240. Murray District, males 1142; females 416. Western Port, males 2516; females 1009. County of Grant and Geelong, males 2339; females 1531. Portland District, males 4130; females 1610—total, males 20,199; females 12,696. The births registered in the year 1845 were 1554; the marriages 332; the deaths 341. The children at school were 2200; the convicts 75.

In 1851 the population was 77,360, of which the following details may be interesting:—Population of towns: Melbourne, 23,143; Geelong, 8243; Portland, 1025; Belfast, 964; Warrnambool, 383; Kilmore, 1137; Kyntor, 296; Seymor, 117. Counties and districts: Banke, 17,469; Grant, 4469; Normanby, 1505; Dundas, 911; Follet, 648; Vilhas, 2705; Heytesbury, 59; Ripon, 814; Hampden, 729; Grenville, 322; Polworth, 1552; Talbot, 893; Dalhousie, 790; Anglesea, 568; Evelyn and Mornington, 871; Gipp Land, 1770; Murray, 2693; Liddon, 1127; Wimera, 2019. In the year 1857 the population had increased to 410,766, of whom 99,354 were located in Melbourne, 23,338 in Geelong, 121,520 in the rural districts, and 166,550 on the different gold fields. In 1858 the population had reached 480,000, so that in seven years no fewer than 400,000 had been added.

The following are the births, deaths, marriages, and population for seven consecutive years, from 1851 to 1857:—

Years.	Births.	Deaths.	Marriages.	Population.
1851 . . .	3,047	1,165	1,323	83,350
1852 . . .	3,756	2,105	1,958	148,627
1853 . . .	5,000	5,000	no return	198,496
1854 . . .	7,542	6,261	3,765	273,865
1855 . . .	11,941	6,603	3,846	319,379
1856 . . .	14,406	5,723	4,116	348,460
1857 . . .	17,490	7,455	4,524	463,135

The following is the emigrants' arrival during the same period:—

	Government Emigrants.			Unassisted Emigrants.		
Years.	Male.	Female.	Total.	Male.	Female.	Total.
1851 . . .	1,082	905	1,982	7,512	1,517	9,029
1852 . . .	7,762	7,715	15,477	67,113	12,077	79,187
1853 . . .	5,236	9,342	14,578	60,796	16,938	77,734
1854 . . .	5,456	10,862	16,318	51,913	15,179	69,092
1855 . . .	3,149	6,096	9,245	44,740	12,586	57,326
1856 . . .	1,763	2,916	4,679	26,572	10,343	36,915
1857 . . .	5,429	8,940	14,369	35,461	13,400	48,861
Totals	29,877	46,776	76,653	224,104	82,040	376,144

On the 31st of March last, the population of the colony is thus stated:—Population on the 31st of December, 1858, 323,447 males, 180,731 females; increase by emigration during the quarter ending the 31st of March, 1859, 1912 males, 2480 females; increase by excess of births over deaths during the quarter ending the 31st of March, 1859, 1078 males, 1452 females. Total population, 511,100.

The next Table gives the revenue and expenditure of the settlement from 1836 to 1842:—

	Revenue.			Expenditure.		
Years.	£	s.	d.	£	s.	d.
1836	0	0	0	2,164	16	8
1837	2,558	15	10	5,879	2	4
1838	2,825	17	10	16,030	2	5
1839	14,703	5	10	24,035	10	4
1840	36,856	1	6	41,374	18	4
1841	81,673	10	4	74,324	19	4
1842	84,566	9	3	91,156	10	11

The revenue has increased so much, that it amounted in 1836 to £89,117; and in 1854, according to the financial minute of his Excellency Sir Charles Hotham, to £2,479,461 8*s.* 1*d.*

As the first great source of productive wealth was from squatting or depasturing stock on crown lands, the following statistical information in reference to its rise may be interesting. In September 1846, the following return was made by the Crown Land Commissioners of the various districts:—

Western Part.—Acres in cultivation, 2586; horses, 1974; cattle, 41,021; sheep, 618,392. Population—males, free, 1659; females, 473; males, bond, 43: total, 2175.

Portland Bay.—Acres in cultivation, 2286; horses, 2906; cattle, 55,136; sheep, 1,085,466. Population—males, free, 2408; females, 586; males, bond, 4: total, 2998.

Murray.—Acres in cultivation, 1291; horses, 1297; cattle, 60,682; sheep, 166,978. Population—males, free, 588; females, 178; males, bond, 50: total, 816.

Gipp's Land.—Acres in cultivation, 264; horses, 595; cattle, 29,191; sheep, 78,319. Population—males, free, 307; females, 71; males, bond, 20; females, 0: total, 398.

Bourke.—Acres in cultivation, 749; horses, 348; cattle, 11,249; sheep, 73,831. Population—males, free, 362; females, 198; males, bond, 1; females, 1: total, 562.

Grant.—Acres in cultivation, 867; horses, 360; cattle, 4897; sheep, 128,414. Population—males, free, 348; females, 129: total, 477.

Grand Total.—Acres in cultivation, 8043; horses, 7580; cattle, 202,170; sheep, 2,151,400. Population—males, free, 5673; females, 1635: total, 7306. Males, bond, 117; females, 2; total, bond, 119.

The increase of stock in the colony is very surprising. The following Table exhibits the numbers in the settlement each year for six years:—

Years.	Horses.	Cattle.	Sheep.
1843	6,278	167,200	1,603,000
1844	7,076	187,900	1,861,000
1845	9,289	231,600	2,450,000
1846	11,400	290,400	2,997,000
1847	14,153	344,300	4,398,000
1848	16,495	386,700	5,130,000

In 1851 the stock of the colony had increased to 21,219 horses, 378,806 cattle, and 6,032,783 sheep; and in 1858 the numbers were 55,683 horses, 614,532 cattle, and 4,766,022 sheep. The quantity of stock slaughtered in 1858 was 197,947 cattle, 998,824 sheep, and 25,249 pigs.

The following return shows the number of vessels (and their tonnage) which arrived and departed from Victoria during six years, from 1852 to 1857:—

VESSELS INWARDS.

Years.	Great Britain. No.	Great Britain. Tonnage.	British Possessions. No.	British Possessions. Tonnage.	United States. No.	United States. Tonnage.	Foreign States. No.	Foreign States. Tonnage.
1852..	251	168,919	1364	225,446	13	5,829	29	8,001
1853..	630	284,719	1740	351,066	119	53,988	105	31,700
1854..	650	349,342	1715	353,419	78	40,206	153	51,646
1855..	274	207,800	1443	274,180	50	27,173	130	39,223
1856..	214	197,033	1512	274,794	55	35,328	99	31,454
1857..	307	290,680	1756	330,594	50	36,841	75	36,449

VESSELS OUTWARDS.

Years.	Great Britain. No.	Great Britain. Tonnage.	British Possessions. No.	British Possessions. Tonnage.	United States. No.	United States. Tonnage.	Foreign States. No.	Foreign States. Tonnage.
1852..	68	36,936	1305	286,163	1	222	41	26,975
1853..	94	61,321	1922	471,817	3	2,105	249	129,624
1854..	88	66,876	2082	532,133	12	4,137	427	195,691
1855..	81	66,711	1637	874,820	9	2,439	265	104,208
1856..	65	57,037	1705	384,489	4	1,094	185	95,787
1857..	64	64,717	1879	426,854	3	1,224	261	191,731

The following Table shows the number of persons and places of worship belonging to the principal religious denominations in the years 1851 and 1857 respectively, in Victoria:—

	1851.		1857.	
	Persons.	Churches.	Persons.	Churches.
Church of England . . .	37,433	8	175,418	99
Presbyterians	11,628	8	65,935	55
Wesleyan Methodists . .	4,988	5	28,305	192
Other Protestants . . .	4,313	2	27,521	50
Roman Catholics . . .	18,014	5	77,351	64
Jews	363	1	2,208	4
Mahomedans	201	0	27,254	0
Residue	424	0	7,614	0

In the head "other Protestants," are included 10,858 Independents, 6484 Baptists, 6574 Lutherans, and 1480 Unitarians, besides 2125 belonging to minor sects.

The following Table exhibits the number of post-offices, the number of letters and newspapers which passed through the General Post-office, the revenue and expenditure of the department for seven years, from 1851 to 1857 inclusive:—

Years.	Number of Letters.	Number of Newspapers.	Number of Post-offices.	Revenue. £ s. d.	Expenditure. £ s. d.
1851	504,425	456,741	44	7,929 9 1	11,483 7 5
1852	972,126	709,837	46	12,453 12 9	25,312 0 0
1853	2,038,999	1,616,789	62	25,783 12 11	73,036 10 0
1854	2,674,384	2,394,941	95	66,939 4 7	143,462 14 4
1855	2,990,992	2,349,656	89	80,108 13 9	106,118 6 9
1856	3,220,614	2,906,141	125	84,941 0 11	93,681 18 0
1857	3,892,981	2,981,970	152	77,662 12 1	96,242 11 9

In the year 1857 the number of letters delivered inland was 2,415,933, and despatched to other countries 1,484,048; the newspapers delivered inland were 1,333,439, and despatched to other countries 1,648,531.

The gold exported since 1851 has been 19,451,964 oz., of which the following are the details:—In 1851, 145,146 oz.; 1852, 1,974,975 oz.; 1853, 4,497,723 oz.; 1854, 2,144,699 oz.; 1855, 2,576,745 oz.; 1856, 3,003,811 oz.; 1857, 2,729,655 oz.; 1858, 2,536,983 oz.; 1859, 842,222 oz.; part of the year only. This makes a fair allowance for the amount carried by private hands, which is known to have been considerable previous to the legislative enactments imposing an export duty. The following are the amounts passed through the Customs:—1851, 145,137 oz.; 1853, 1,988,527 oz.; 1854, 2,144,699 oz.; 1855, 2,751,536 oz.; 1857, 762,460 oz. According to the returns, the annual value of the gold produced during the last few years has been £11,000,000; the value of wool, £1,500,000; of agricultural crops, £2,500,000; stock fisheries products and manufactures, £5,000,000; making a gross production of £20,000,000 per annum.

The following statistics of the lands of Victoria are taken from the books in the Crown Land-office, Melbourne:—

Area of land in the colony	55,644,160 acres.
Number of holders of purchased land	13,163
Acres of purchased land in occupation	2,113,134
Acres in crop	237,729
Occupied acres of purchased land not cultivated	1,875,405
Quantity of land sold by the crown during the last ten years	2,541,913
Quantity of unsold land	52,882,544
Amount realized for land during the last ten years	£6,636,555
Average price per acre	£2 12 6
Average price per acre in 1857	£2 2 6

There had been sold in 1851, 99,769 acres to 77,345 persons, or about an acre and a quarter to each; at the end of 1857 there had been alienated 2,748,415 acres to 450,000 persons at the rate of six acres to each. In the year ending the 31st of March, 1857, the number of holders of purchased land was 7523. The extent of their holdings was 1,532,358 acres; the acres in crop were 179,982. In 1859 the holders were 11,554, the extent of holdings 2,492,443; the acres in crop were 297,055; in the same period the population had increased from 410,000 to 512,000. Recent tables demonstrate that the total amount of land alienated from the crown in Victoria in 1857 was 2,748,415 acres, and in 1859 it is upwards of 3,000,000 of acres; of this quantity, no less than 2,592,443 acres were in the hands of agriculturists, and 1,731,929 acres enclosed, and 297,055 under cultivation. The neighbouring colony of South Australia, which is, properly speaking, an agricultural colony, had, in 1857, a population of 109,917 and 235,965 acres in cultivation.

The following Table exhibits the acres in cultivation during the two years 1858 and 1859:—

	1859. Acres.	1858. Acres.
Barley	5,296½	5,409
Maize	489½	445
Rye and Bere	56½	132½
Peas, Beans, and Malt	268	—
Potatoes	29,822½	20,697½
Turnips	331½	355
Mangol Wurzel	124¼	119
Red Beet	3	7⅛
Carrots and Parsnips	95½	56
Cabbage	51¼	—
Bare Fallow	5,938¾	—
Hay	85,836	75,536
Cereal Grasses	3,809¾	1,277
Maize	278¾	357
Lucerne	285	163¼
Clover	370	277¼
Sorghum	23½	—
Permanent Grass	2,508	—
Gardens	5,475	4,657¾
Tobacco	66½	71
Vines	530¼	401½
Other crops	297¼	4
Orchard	387¾	310

There are, wheat 77,705 acres for 1857, and 87,230 acres for 1859; and oats 76,935½ acres for 1859, and 40,222½ for 1858.

The produce was as follows:—

	1859.	1858.
	Bushels.	Bushels.
Wheat	1,551,004½	1,808,438½
Oats	2,131,155½	2,249,800
Barley	114,432	156,458
Maize	9,674	6,558
Rye and Bere	611	—
Peas, Beans, and Malt	4,825½	2,797
	Tons.	Tons.
Potatoes	106,461½	51,115½
Turnips	1,254¾	1,583¾
Mangol Wurzel	2,106½	2,876
Red Beet	1½	27½
Carrots and parsnips	520½	240⅜
Cabbage	142	—
Hay	112,672¼	137,475½
	Cwt.	Cwt.
Onions	297	5½
Tobacco	932	717

Number of vines, 952,107; fruit sold, 3404½ cwts. in 1859, 4629 in 1858; wine produced in 1859, 7650 gallons; in 1858, 5761 gallons. Brandy manufactured, 132 gallons in 1839.

The following is a comparative view of the population and commerce of Victoria:—

Population. Years.	Average of Year.	Value of Imports. £	Value of Exports. £
1839 . . .	7,000	205,000	78,000
1846 . . .	34,000	316,000	425,000
1852 . . .	130,000	4,604,000	7,452,000
1856 . . .	360,000	14,115,000	16,000,000

The following Table gives the averages of these years:—

Yearly average.	Yearly average of population.	Imports. £	Exports. £
1835 to 1840, 6 years . . .	5,000	121,000	46,000
1841 to 1846, 6 years . . .	23,500	250,000	295,000
1847 to 1852, 6 years . . .	74,000	1,190,000	2,003,000
1853 to 1857, 5 years . . .	300,000	14,514,000	13,861,000

The following is a comparative view of the number of sheep and the wool exported during 1855, from Victoria and New South Wales:—

	Sheep, Number.	Wool, lbs.
Victoria	5,332,000	22,353,000
New South Wales. . . .	8,144,000	17,671,000

On the Trade Currency of China (with specimens of the coinage). *By* Dr. Macgowan.

Statistics of Small-Pox and Vaccination in the United Kingdom. *By* Dr. W. Moore.

During the past year, 100,000 deaths occurred in the United Kingdom, which were preventable or removeable. Of children alone, between 30,000 and 100,000 die annually from various infectious and respiratory diseases alone. According to the Registrar-General's Report for the year ending December 1858, the Registrars received 376,798 vaccination certificates, although they registered births of 655,647 children. The writer set down the deaths in England and Wales, from small-pox annually, at 4000, and 3990 cases could be cured by vaccination. Small-pox contributed no less than 30 per cent. of the mortality of Dundee. The case of Ireland was alluded to as rendering necessary a system of registration.

On Decimal Coinage. *By* Colonel Shortrede.

On Church Building in Glasgow. *By* John Strang, *LL.D., Glasgow.*

From 1839 to 1849, 35 churches were erected; from 1849 to 1859, 53 churches —total, 88 churches. Of these, 8 were erected by the Established Church, 35 by the Free Church, 17 by the United Presbyterian Church, 10 by the Independent Church, 7 by the Roman Catholic Church, and 11 by other denominations. The cost of the various churches was—Established, £5744; Free Church, £167,698; United Presbyterian, £119,154; Independent, £59,722; Roman Catholic, £31,364; other denominations, £30,664. During the last twenty years there had been an addition in the Church accommodation of Glasgow, within its municipal limits, of no less than room for 73,625 persons, at a cost of £444,348. The increase in the population during that time was £145,000, making one sitting for every 1600 of them.

On the Past, Present, and Prospective Financial Condition of British India. *By* Colonel Sykes, *M.P., F.R.S.*

After observing that for years past the financial condition of our Indian empire had been the subject of the most conflicting statements, arising from the confusion inseparable to the ceaseless wars which had been carried on, which, from their enormous cost, had necessarily involved Indian finances in confusion, Col. S. stated that in 1842 he had caused a statement to be drawn up in the proper department of the India House of the real condition of the receipts and expenditure of India. These statements were continued from 1842 to 1857, embracing five decennial periods from 1808 onwards to 1857, when exact returns terminated with the mutiny year. Under the various heads of progress of revenue, progress of charge, progress of civil charges, progress of military charges, progress of interest of debt, he gave at great length the results of those returns, which it is, from their length and multiplicity of figures, impossible to abstract, and concluded by the following deductions:—1. That expenditure in the military branch of the service can be reduced whilst the highest efficiency was preserved. 2. That the progressive increase of debt was necessary and inevitable. It was an object to link the interests of the native capitalists in India with those of the British Government through the medium of pecuniary obligations. 3. That the pressure of the interest of the debt of India in relation to the revenues in 1857, before the mutiny was 7·19 per cent, and the debt 1·79 year's purchase of revenue. Since the mutiny, it was, after all, only 9·34 per cent, and the purchase 2·43. 4. That the revenues of India have increased to a greater ratio than the interest of the debt. 5. That there was a satisfactory prospect in the ultimate productive working of the amount of silver, which has been poured into India, and remained there since 1800, which was, in fact, the balance of trade in favour of India. 6. That on a right understanding of the past financial condition of India, and a proper knowledge of the resources of the country, depended the success of the hazardous experiment of increased taxation. 7. That there was ample proof of the progressive financial strength of the government, of increasing confidence on the part of the public mind, and of the large disposable capital in India. 8. That the finances were gradually and steadily growing healthy, as shown by Parliamentary paper, No. 201, Session 2.

On Illegitimacy in Aberdeen and the other large Towns of Scotland. *By* James Valentine.

The published returns by the Registrar-General of Scotland on this point date only from 1st January, 1858, but the comparatively unvarying experience of eighteen months which his reports illustrate, has already well nigh fixed down a certain character on the various towns and districts in Scotland, and especially a bad one on this town. Some explanation, at least, is therefore required.

The proportion per cent. of illegitimate to legitimate births, is about 6·5 in Sweden, 6·6 in Norway, 6·7 in England, 6·7 in Belgium, 7·1 in France, 7·1 in Prussia, 9·3 in Denmark, 9·8 in Hanover, and 11·3 in Austria. In London it is about 4 per cent., in Liverpool above 4½ per cent., in Birmingham under 5 per cent., and in Manchester about 6 per cent. (Chambers's Information). In Scotland, during 1858, it was 8·8 per cent., made up thus:—

In the eight principal towns	8·4
Districts, including smaller towns	8·6
Country districts	9·3

Taking the eight principal towns by themselves as they stand in the Registrar's Reports, the following results appear:—

	Year. 1858.	Half-year. Jan. to June. 1859.	Mean rate. Per cent.
Aberdeen	14·9	15·7	15·2
Dundee	10·1	10·8	10·4
Perth	9·6	9·1	9·3
Paisley	7·3	9·3	8·3
Edinburgh	8·7	7·8	8·2
Glasgow	7·7	7·4	7·5
Leith	5·9	7·8	6·8
Greenock	4·7	5·0	4·8

It may be stated, though the figures have not been officially published, that the registers here for the three previous years, namely, 1855, 1856, and 1857, show a rate for our two parishes of 12·6, 13·3, and 13·6 respectively.

The mean marriage ratio in the eight principal towns in Scotland, in the four years 1855–1858, was, in 10,000 persons,—

	Mean.		Mean.
Greenock	100	Leith	80
Glasgow	89	Paisley	77
Perth	85	Edinburgh	76
Dundee	81·7	Aberdeen	64·5

The birth ratio in the eight principal towns in Scotland during the years 1855, 1856, 1857, and 1858, was (in 10,000 persons living)—

Perth	277·75	Paisley	357·75
Edinburgh	290·00	Dundee	370·00
Aberdeen	299·25	Glasgow	405·75
Leith	331·25	Greenock	499·25

The excess of females over males in the eight principal towns in Scotland, according to the Census of 1851, was as follows:—

Greenock	4·2 per cent.	Dundee	9·2 per cent.
Perth	4·6 do.	Edinburgh	9·8 do.
Glasgow	5·8 do.	Leith	9·8 do.
Paisley	8·0 do.	Aberdeen	11·8 do.

From these various data, the following conclusions seem to be deducible:—

1st. That where there is a low marriage proportion, there will be a high rate of illegitimacy.

2nd. That the same result will follow when there is a marked excess of females over males.

The following Table shows the proportion of illegitimate births, and employment of the mothers in Aberdeen:—

	1855.	1856.	1857.	1858.	Half-year. Jan. to June. 1859.
Total births	2156	2419	2401	2396	1039
Illegitimate	272	323	329	357	195
Proportion of illegitimate births	7·9	7·4	7·2	6·7	5·3
Employments of mothers:—					
Domestic servants	69	111	93	98	45
Factory operatives	101	72	87	119	78
Farm servants	13	20	35	33	17
Dressmakers	19	26	25	18	4
Widows	5	6	15	10	4
Housekeepers	4	15	10	12	4
Miscellaneous	61	73	64	67	43

There were, at the period of the census of 1851, 3200 domestic servants in Aberdeen within the Parliamentary boundary; the number is now probably 3400. The female factory operatives at the same period numbered 4400; but now they number, as nearly as can be learned, 3600.

The residences of mothers of illegitimate children registered in Aberdeen for the half-year ended June last, shows very distinctly that in the districts where the lower class of houses are situated, there does illegitimacy most prevail. It may also be stated that an exceedingly small proportion—in fact, scarcely a case—occurs where the mother moves in the middle or upper ranks of society. A very large number of the mothers, it may be added, sign the birth register by means of marks, being unable to write their own name.

The writer mentioned several peculiarities in the case of Aberdeen, which combine in a greater measure than in that of any of the other large towns of Scotland, to produce or aggravate the evil of illegitimacy. These were, chiefly, the geographical position of the town, as (so to speak) the metropolis of a vast rural district, in which district the evil referred to abounds; the great excess of females, and the want of adequate employment for them, in Aberdeen, which leads, it is believed, to occasional prostitution, and thus to illegitimacy; and various hindrances that exist to marriage. He also pointed out, that the area included in the boundary of the city for registration purposes is so unequal in the case of Aberdeen, and the other large towns, as to prevent any fair comparison. He further showed that as many of the Registrar-General's deductions are (necessarily) founded on estimates of the population, some of those deductions must be modified by the census of 1861.

Notes on the Statistics, chiefly Vital and Economic, of Aberdeen. *By* JAMES VALENTINE, '*Journal*' *Office, Aberdeen.*

The population of Aberdeen was 4000 in 1572, and 15,730 (according to Webster's enumeration) in 1755. At the commencement of the century it was 26,992; in 1821, 43,825; in 1851, 71,973. This embraces the Parliamentary boundary, which includes a suburban and partly rural district: the town proper, *i. e.* the area covered by streets, is about two miles square; the Parliamentary boundary is about ten miles square. For purposes of registration of births, &c., again, an additional district, wholly rural, and of about two miles square, to the north of the Parliamentary boundary, is included. At present the purely *town* population is estimated at 71,000; the suburban, including Old Aberdeen, a small burgh by itself, and Woodside, a village, at 7000; and the rural at 2000=80,000. It is probable, however, that the actual population of the city itself is somewhat below the figure mentioned.

1. *Vital statistics.*—With respect to *births,* we have no data of any worth referring further back than the year 1855, when the General Registration system for Scotland came into operation. Before that time there was a register of *baptisms* only, which, from various causes, chiefly perhaps the indifference of the public, was very incomplete. The births registered in the registration boundary of Aberdeen for 1855, 1856, 1857, and 1858, were 299·25 in 10,000 persons living (according to estimate of population). Comparing this with the birth ratio in the other larger towns of Scotland, we find the proportion for Perth to be the lowest, viz. 277·75, and Greenock the highest, viz. 499·25.

2. *Marriages.*—The marriage ratio in Aberdeen is the lowest of any of the larger towns in Scotland. For the four years 1855–58, it was 64·5 in 10,000 of the people (estimated). The highest marriage ratio among the principal towns of Scotland for the same period was in Greenock, namely, 100 in 10,000 of the population.

3. *Deaths.*—The death ratio in Aberdeen for the four years 1855–58, was 212·25 in 10,000 persons; in Edinburgh for the same period it was 232; in Glasgow, 294·25; and in Greenock, where the death ratio is highest of the principal towns, it was 328·25. The proportion of children *under five years of age* who died yearly in Aberdeen in the above four years was 32·2 per cent.; in Edinburgh, 38·6 per cent.; in Glasgow (where this mortality is highest), 53·9 per cent. More than one-half of the deaths in Glasgow are of children under five years of age! The average monthly mortality in Aberdeen for seven years, 1852 to 1858 both inclusive, shows that the fewest deaths occur in August, viz. 116; next, July, 128; then September, 130: February and March show the highest mortality, 158 of the deaths occurring in each of these two months. Among the large towns in Scotland, Aberdeen shows, so far as data have been given, the least number of deaths occurring where the benefit of medical aid was not experienced.

The above comparatively favourable results as to the mortality of the town are owing, in a considerable measure, to the fact of the large suburban and rural districts above referred to, which are very healthy, being included in the area. It has to be mentioned also, that the number of *inhabited houses* within the Parliamentary boundary of Aberdeen in 1851 was in the proportion of 1 to 12·3 of the population: in Dundee it was 1 in 15·6, in Edinburgh 1 in 20·6, and in Glasgow 1 in 27·5. The maximum supply of water to the town is 1,250,000 gallons daily for (say) 67,000 of the inhabitants,—the supply to several manufactories being, however, included in this quantity, which is therefore somewhat insufficient in a sanitary point of view.

The water is pumped into the town from the river Dee, the bed of which for several miles above the water-works is granite,—a circumstance favourable to the quality of the water for the purposes of the town.

Economic, &c. statistics.—In the N. S. *Savings' Bank* the amount deposited in the year ending 31st Dec. 1849, was £29,740; in 1858, the amount was £55,307. The number of operative accounts at the former date was 6183; at 31st Dec. 1858, 9000. The total amount at the depositors' credit rose, in the same period, from £95,400 to £191,731. In 1858 there were deposited in the seven principal *Penny Banks* of the town, by 1853 depositors, the sum of £1155 17*s.* 6*d.*—being about the average for two or three previous years. In 1858 the published accounts of Yearly Deposit and Friendly Societies in the town and neighbourhood exhibit a membership of 10,279—nearly one-half, or 4753, being females. During the above year these Societies expended £832 9*s.* 4*d.* in sick and funeral money to members, and funeral money to wives and children of members. The amount deposited and withdrawn is not stated.

The number of *paupers* in Aberdeen and suburbs has decreased from 2457 in 1849 to 1919 in 1858. The amount of *heritable property* (rental) within the Parliamentary boundary in the books of the Valuation Assessor is within a small fraction of £200,000. In 1853, when the writer took up an *educational* census of the town (Parliamentary boundary), the following results appeared: viz. 147 schools, with 10,488 pupils on the roll, being about 1 in 7·5 of the population. As an index to the educational state of the community, it appears that, during the three years 1856–7–8, of the persons who reported 13,846 births, deaths, and marriages at the Registrars' offices, 1957 signed their names by marks, being unable to write. The number of *commitments* to the Aberdeen *prison* in 1849 was 1011; in 1854 it fell to 756; in 1858 it was 885. The number who *emigrated* from Aberdeen direct to British North America (chiefly) was, in 1849, 293; it rose in 1854 to 1598, and has since gradually declined to 234 during the present year (1859). The number of *letters* which passed through the Aberdeen post-office in 1858 was 2,454,920, as compared with 1,550,640 in 1854. The number of money-orders issued and paid together in 1858 was 40,779, involving a total sum of £78,721, as compared with 35,036, involving £67,585, in 1854. A Table was also exhibited showing the above particulars at one view for each year from 1849 to 1858 inclusive, together with the fiars' price of oatmeal for each year.

On the British Trade with India. *By* R. Valpy.

The author stated that in the year 1858 the exports of British produce from England to India amounted to £16,782,515, and exceeded those to the United States, which were not more than £14,510,616, a low amount, it is true, for the United States. In the first six months of 1859, the value of British produce exported has been £11,783,796 to the United States, and £10,109,563 to India. In 1815, the first year after the opening of the Indian trade to British merchants, the total value of the imports and exports of this country from and to India, amounted to £10,701,000; in 1858 the amount was £31,754,000. In 1858, therefore, the value of the British trade with India was three times more than it was in 1815. The computed real value of the total imports from India in each year since 1854, when the real value of imports was first ascertained at the Custom House, was—

1854	£10,672,000
1855	12,688,000
1856	17,262,000
1857	18 650,000
1858	14,972,000

This increase is not so striking as that of the exports of British produce to India, on a comparison of similar periods, viz. from 1855 to 1858 over 1815 to 1819—the totals for the respective periods being about £11,600,000 against £2,800,000. In 1850 there was a large increase in the imports of Indian cotton, the quantity being 118,872,742 lbs., which have since steadily augmented. The paper noticed the various articles of imports and exports, showing that India is the best customer we have for the most important of our industrial productions. For example, in

1854 the quantity of cotton manufactured goods exported was only 39,000,000 yards, and in 1858 it rose to 728,000,000 yards. The total value of our exports of cotton stuffs and yarns to India in 1858 was £10,249,826. Machinery has been exported to India since 1855 to the extent of half a million annually.

On the Statistics of Colour-Blindness. By Professor GEORGE WILSON, *M.D.*

The object of this communication was to urge the importance of an extended inquiry into the prevalence of colour-blindness. The number of persons markedly colour-blind was, according to

Dalton (1st determination)	12 per cent.
Dalton (2nd determination)	8 ,,
Pierre Prevost	5 ,,
Seebeck	12 ,,
Kelland	2 ,,
G. Wilson	1·8 say 2.

In a recent Report to the Royal Society, Sir John Herschel has expressed his surprise at the high per-centage obtained by the author, which appeared to him incompatible with the *apparent* rarity of colour-blindness among his own circle of acquaintances. Dr. Wilson's figures, however, are the lowest which have been given, and they were obtained by the examination of 1154 persons, the largest number which has hitherto been examined in reference to their vision of colour. How far the per-centage thus obtained represented the condition of the entire community, it was impossible to decide. That colour-blindness, nevertheless, was far from being very rare, and that its comparative abundance had, in relation to workers in colours and to railway and naval coloured signals, an important bearing on many professions, and on the welfare of the entire community, the author illustrated by many examples, ending by asking the assistance of the Section in collecting its statistics.

MECHANICAL SCIENCE.

On the Rivers "Dee" forming the Ports of Aberdeen and Chester. By J. ABERNETHY, *C.E.*

On Coal-pit Accidents. By Captain J. ADDISON.

The author proposes to detect the presence of the explosive gas in coal mines by the use of balloons filled with hydrogen; and carbonic acid gas, or "choke damp," by the use of balloons filled with common air. These, when introduced into a mine, would at once show the force of gravity, the nature and extent of the gaseous accumulation; ventilation might then be accomplished by the introduction of copper cylinders filled with compressed atmospheric air, which could be liberated, and thus expel the noxious gases.

On an Improved Method of maintaining a True Liquid Level, particularly applicable to Wet Gas-Meters. By ALEXANDER ALLAN.

The author proceeded to explain the working of a model and drawings illustrating his method of measuring the consumption of gas, and explained that, whereas by the present law an error ranging up to 5 per cent. was legalized, by the plan proposed, tried under severe tests, and in actual operation with gas passing through in a considerably greater quantity than the size was calculated for, the result was that the maximum per-centage of error amounted to only one-fourth per cent., a result hitherto unequalled.

On a Safety Cage for Miners. By ROBERT AYTOUN.

To cause the cage, on the failure of the winding tackle, to cling to the guide-rods which directs its passage down the shaft, is the object sought in all safety cages. The author's plan for effecting this is a mere adaptation of an instrument well known to miners—the key or wrench used for raising and lowering the boring rods. It has never been known to lose its hold, and the greater the strain the firmer is its gripe. To adapt this instrument to the cage, a slight modification of the upper shoes or slides is all that is necessary. These shoes or slides are, as usual, two in number, and placed on opposite sides of the cage and in opposite directions. Each of them has a single bolt or stud by which it is attached to the cage, and around which it turns, a long arm to the extremity of which the winding-chain is attached, a stop which prevents the arm from being pulled above the horizontal line, and a spring which lowers it when the winding-chain is slack. The author illustrated the various parts by diagrams and a working model.

On Harbours of Refuge. By DONALD BAIN.

On a Boat-lowering Apparatus. By A. BALTEN.

On an Artesian Well in the New Red Sandstone at the Wolverhampton Waterworks. By J. F. BATEMAN, *C.E., F.R.G.S., F.G.S.*

The town of Wolverhampton has been, up to a recent period, supplied with water produced by two deep shafts, one sunk about 300 feet deep into the lower new red or Permian measures, and the other to a somewhat similar depth in the new red sandstone proper. From both of these wells a large quantity of water was anticipated by the engineer who advised their construction, but their yield is under 200,000 gallons a day each, the water being pumped, in one case, from a depth of about 180 feet, and in the other 246 feet.

The quantity thus yielded being insufficient for the supply of the district, new works have been constructed, which I have just completed, for bringing water from the river Worth at Cosford Bridge, about nine miles from Wolverhampton, and three from Shiffnall in the county of Salop.

The works are constructed for the supply of 2,000,000 gallons per day, and the water has to be forced to a height of 500 feet for the supply of the town.

The river Worth, at the place at which the pumping works are constructed, is not more than 40 or 50 feet above the Severn, which it joins at Bridgenorth, about eight or ten miles distant. It may therefore be considered to be at the bottom of a basin a little elevated above the sea. From the character of the surrounding hills, and the inclination of the beds of the new red sandstone, it appeared to me very likely that, although the wells which had previously been sunk on the high plateau of Wolverhampton had proved comparative failures, a considerable quantity of water might be found in the sandstone at Cosford Bridge, and that possibly some might rise to the surface and flow as an artesian well. I therefore obtained the sanction of the Directors of the Company to sink a bore-hole for the purpose of ascertaining the fact.

In some parts of the country, as in Cheshire and Lancashire, on the shores of the Mersey, the new red sandstone is very clearly divided into four distinct portions, consisting of an upper hard mass, about 300 or 400 feet thick, a soft mass, about the same thickness, a second hard mass, and a lower soft mass,—all of pretty much the same thickness. In the neighbourhood of Wolverhampton and Shiffnall these distinctions are not so clearly exhibited; but I had reason to believe, from the position of the works, that a bore-hole, of about 200 feet in depth, would pierce the hard rock on which they were situated, and reach the soft rock beneath.

The bore-hole was commenced 12 inches in diameter, and continued at that size for 70 feet in depth, when it was diminished to 7 inches, and continued for 190 feet, making a total depth from the surface of 260 feet.

The first water was met with at a depth of 22 feet 4 inches, and from that time it rose to the surface and flowed over as an artesian spring, constantly increasing in quantity as the depth increased, till the boring was discontinued; at which time it amounted to about 210,000 gallons per day.

The following Table will show the manner in which the water increased:—

Depth below surface. ft.	in.	Yield in 24 hours. galls.	Depth below surface. ft.	in.	Yield in 24 hours. galls.
25	4	2,880	119	0	37,028
29	4	3,553	123	6	43,200
37	6	3,602	142	4	64,800
45	0	5,400	159	2	74,055
63	3	9,257	169	6	86,400
78	6	18,514	178	11	129,600
86	9	21,600	185	6	130,896
95	0	23,563	211	1	163,200
104	0	25,920	221	7	183,600
111	2	32,400	260	0	209,830

Throughout the whole depth of boring the rock varied little in character: it was nearly all hard rock; sometimes very hard, with occasional beds of softer stone. For the last 40 feet or so the soft beds were thicker, but otherwise there was little change from top to bottom.

The greatest increase of water took place at 214 feet and 227 in depth, at each of which depths there was an increase of 20,000 gallons per day. The soft rock I anticipated was not met with at the depth I expected, but sufficient was done to prove the abundance of water. A larger bore-hole, which would permit the ascent of a larger column of water, would materially increase the produce as an artesian well; while a shaft sunk 30 feet or 40 feet deep, and exhausted to that depth by pumping, would yield a very considerable quantity. As the whole rock is charged with water to the level of the river which forms its natural outlet, and as the boring shows that the lower beds receive their supplies from distant sources, the supply to be obtained may reasonably be expected to be inexhaustible, within the limits of that which is due to the percolation of the rain upon the collecting area.

Description of the Glasgow Waterworks, with Photographic Illustrations taken at various stages of the work. By J. F. Bateman, *C.E., F.R.G.S., F.G.S.*

On Coal-burning without Smoke, by the method of Steam-Inducted Air-currents applied to the Locomotive Engines of the Great North of Scotland Railway. By D. K. Clark, *C.E.*

The whole apparatus is external to the fire-box, and therefore not exposed to heat, and it is controlled in the most perfect manner by a single stopcock. Air is admitted above the fuel by one or more rows of tubes inserted through the walls of the fire-box, and jets of steam are projected through the air-tubes from nozzles $\frac{1}{16}$th of an inch diameter, in small steam pipes, placed outside the fire-box, to increase the quantity and force of the air admitted above the fuel, in order to consume the smoke. The jets of steam are used principally when the engine is standing, with the aid of a light draught from a ring-jet in the chimney, to carry off the products of combustion; and they may be shut off when not required. The supply of air through the tube may also be regulated by dampers.

The grate-bars are placed close together, with narrow air spaces, and the ash-pan and damper are tightly fitted. The level of the fuel should at all times be below the air-tubes. By the adoption of this method it requires a less weight of coal than the engines formerly required of coke for the same duty, and thus saves more than the whole difference in price of the two fuels.

Description of a Patent Pan for Evaporating Saccharine Solutions and other Liquids at a temperature below 180° Fahr. *By* Richard Davis, *F.S.A., F.L.S.*

This consists of a cast iron, copper, or other pan, through which is inserted a series of copper tubes, similar to those used in a locomotive boiler. On each side of the pan, to which the tubes are riveted, is a cast-iron steam chest, with stops, to ensure a circulation of the steam through the tubes in a serpentine manner. Between these tubes a series of copper discs is made to revolve, the diameter of which is 3 feet, and the thickness about $\frac{1}{8}$th of an inch.

The condensed water from the tubes, caused by the evaporation of the liquid in the pan, is received in an ordinary condensing box, fitted with a ball and valve, and is thence conveyed to a receiver, ready for readmission to the boiler at a temperature of 160° or 170° Fahr., according to that of the liquid under evaporation.

This method affords the means of evaporating syrups and other liquids at a temperature under 180°, at which temperature sugar will not carbonize.

The economy of fuel in this process is very great, while evaporation is as rapid as when the vacuum pan is employed. The cost of the latter (the method of working it requiring skilled labour of a superior degree) is such, as to place it out of the reach of most proprietors in the colonies, whilst the cost of this pan is trifling, and may be worked by an ordinary boiler-man. For the revolutions of the discs little power is required, as they are supported upon centre bearings, and may be turned by manual or any other motive power.

Every part of the machinery is open to view, and from its extreme simplicity can be cleaned, or any accidental injury repaired by a common workman. One great advantage to be derived from the use of this apparatus is the facility it affords for working up molasses, and thus converting the second product into an article almost equal to that of the first.

On the Engines of the 'Callao,' 'Lima,' and 'Bogota.' *By* J. Elder.

In these engines the steam enters at 42 lbs., and is expanded to nine times, or to $4\frac{2}{3}$ lbs., namely, from 42 lbs. to 14 lbs. in the small cylinder; it then enters the large cylinder at 14 lbs., and is expanded to $4\frac{2}{3}$ lbs.; but as the second piston is three times the size of the first, the gross load will be the same on both pistons, and the piston rods, crossheads, and connecting rods may be duplicates of each other.

From the above pressures of steam at the entering of the cylinder, it is evident that, unless the inside surface of the large cylinder is retained about 210°, condensation of the steam on entering is certain, and such condensation will chiefly evaporate into the condenser while the eduction port is open, and the latent heat necessary to evaporate such condensation will be much greater than what would have radiated from the hot cylinder to the condenser, had no condensation taken place; and such heat would be entirely lost. In the same manner it might be mentioned, that the inside surface of the small cylinder should be retained as high in temperature as the steam that enters it; and in order to attain this object, every effort should be made in the construction of steam machinery. It is evident, that, for the small cylinder, superheated steam is absolutely necessary for this purpose, either in the jackets or cylinder; and in the large cylinder the temperature of steam direct from the boiler to the cylinder may be sufficient, if communicated through a pipe or aperture large enough.

In the engines under description, the pipe supplying steam to the jackets was $2\frac{1}{2}$ in. diameter, and the steam was superheated to upwards of 400 degrees that entered the jacket. It was found that a large supply to the jacket saved a vast quantity of heat, which can only be explained by the principles above mentioned, namely that any quantity of heat supplied to the jackets assisted in proportion to the quantity of latent heat it saved being evaporated to the condenser during the eduction of the steam; and if the pipes to the jackets were large enough, or sufficient to prevent the condensation referred to, the economy of the machinery was realized to the greatest extent.

The writer begs to call the attention of all parties concerned, to the performance of Cornish pumping-engines, and more particularly to the similarity of action of the steam-jacket in these engines to the principle of that of the double-cylinder engine with steam-jackets. In the Cornish engine the piston is single-acting, and the jacket has twice the time to do its work, or rather the steam in the cylinder is twice the time in contact with the jackets that it is generally with Watts' engine; so that the Cornish engines have very large jacket surfaces in proportion to the power developed. With these features in view, the engineers constructed the engines now under discussion, and to this cause may be attributed a considerable portion of their success, and to the non-observance of these features the almost total failure of economy in the expansive working of most steam-engines on board of steam-ships, namely, by constructing large engines, going slow, without steam jackets, or superheating of steam: such engines would, of course, present a most favourable opportunity for improvement by adding any mode of superheating apparatus.

From the foregoing it is also conclusive, that with the ordinary construction of steam-engines afloat, small engines going fast would consume less coal per indicated horse-power than large engines going slow; but with engines such as those of the 'Callao,' 'Bogota,' and 'Lima' the converse will be the case, carried, of course, within moderate limits.

In reversing the engines, the eccentrics are made to overrun the engines by a donkey-engine till they arrive at the backing position, a plan which is less likely to cause accident than the ordinary methods. This donkey-engine has been found to be most satisfactory in its application.

The boilers are tubular, two in number, with iron tubes.

Each boiler has three furnaces, 3 feet 4 inches wide, and 6½ feet long, or making an aggregate of 130 square feet of fire-grate.

The tubes are of iron, 288 in number, 4 inches inside diameter, and 6½ feet long. Each vessel has an oval steam-chest, 12 feet high and 8 feet long, and 5 feet broad, with three uptakes through this steam-chest, each 2 feet diameter and 15 feet long. This makes a strong form of takeup where it joins the tube plate, especially in boilers firing across the ship; the feed-pipe of the boilers enters into a long flat tank or shield in front of the furnaces in which the furnace-doors are formed. This shield forms a protection to the firemen from heat, and makes the heat, otherwise lost, available for the feed water. In the 'Callao' there is a third coil of feed-pipe in the funnel, to heat the feed water. Such then are the leading features of this machinery, and the results are as follows:—

This plan of the boilers gave steam to the engines superheated to about 400 degrees by the uptakes, showing that the various systems of superheating are unnecessarily complicated; indeed, in the 'Lima,' the steam got so far above 400 degrees, that in the 'Bogota' the steam-chests were made 2 feet lower, and two small feed-pipes were made to feed the boiler when too much superheated by a tap in the steam-chest. The superheated steam, though upwards of 400 degrees of heat, was found quite inadequate to prevent condensation in the cylinder, without the steam-jacket cock being fully open.

The writer begs to draw attention to the fact, as in the case of double-cylinder engines it is so prominently observed, by comparing the respective diagrams of the low- and high-pressed cylinders, especially as in those engines the cylinders are so close that the diagram of one is an exact counterpart of the other, when there is no condensation; and it is somewhat curious to observe, while taking diagrams of the low-pressed cylinder, the gradual development of the diagram, with the jacket-cock fully open, compared with that when it is shut.

When the steam was at a pressure of 21 lbs. above the atmosphere, the temperature at the surface of the water was 264 degrees, and at the top of the steam-chest 400 degrees Fahr., showing that the steam was surcharged to the extent of 136 degrees, notwithstanding that the steam was in direct and unimpeded contact with the surface of the water. The engines made during the trial trips, which were generally half a day in length, from about 23 to 26 revolutions, and indicated from 1000 to 1300 horse-power during that time, and consumed from 20 to 25 cwt. per hour, with the surface-blow-off cocks open. The 'Callao,' 'Lima,' and 'Bogota' have all shown a consumption of from 2 to 2½ lbs. per indicated horse-power per hour best Welsh coals, and the speed of the ships from 12½ to 13 knots per hour.

The steam-ship 'Callao' has now been plying between Valparaiso and Panama with Her Majesty's mails, for upwards of nine months, and has performed her work in a most satisfactory manner. The distance between these ports is upwards of 3200 miles, and this she performs regularly on about 300 tons of coals. The 'Callao' made the run from Liverpool to Valparaiso in, I think, about 36 days steaming time, which averages about 240 miles per day during a run of 9000 miles, on a consumption of about 20 cwt. per hour. The 'Lima' has also arrived at her destination, after a most successful run; she performed the distance of 1500 miles, from Valparaiso to Callao, in 141 hours, consuming 150 tons of coals, logging at an average of 260 miles per day during that distance, considerably faster than she had ever done with her original engines, and on less than half the coals consumed. The 'Bogota' was completed and tested on the 1st of September last, and found fully equal to the others. She made the run from the Cloch Light in the Clyde to the Bell Buoy at Liverpool in 15 hours, against a strong head wind, and consumed during that distance 15 tons of Scotch coals.

At the Admiralty trial, which took place immediately on her arrival at Liverpool, she averaged upwards of 13 knots, the engine made $25\frac{1}{3}$ revolutions; she indicated 1080 horse-power, and consumed about 21 cwt. per hour of Scotch coals; the steam was superheated to 340 degrees on entering the cylinder, and the thermometer at the water-level of the boiler showed 264; the pressure in the boilers was 27 lbs., and the vacuum in the condensers 26 inches. She left Liverpool for Valparaiso on the 11th of the present month, with sufficient coals to carry her 5000 miles, at 240 miles per day, and a full complement of stores for the passengers on board; her draught of water on leaving Liverpool at the load line was, aft, 14 ft. 6 in.; forward, 13 ft. 9 in.; and displacement, 1700 tons. She steamed to the Holyhead Light, where the pilot left her, at the rate of $11\frac{2}{3}$ nautical miles per hour against a strong head wind; the engines were making 20 revolutions; the steam pressure was 26 lbs.; the vacuum 26 inches; and the consumption of coals 22 cwt. best Welsh coals per hour.

The engineers are now constructing the machinery for three other steam-ships on this principle, with boilers on the cellular cylindrical spiral principle. In conclusion, the form of engines now described gives regularity of motion while working expansively to the fullest extent, the expansion principle is fully realized, and the engines are of a strong architectural figure, with the various parts easily got at, and reduced to simple forms, and present every facility for reversing freely by the engine-driver.

Experimental Researches to determine the Density of Steam at various Temperatures. By William Fairbairn, *LL.D., F.R.S., and* Thomas Tate.

For a perfect gas, the law which regulates the relation between temperature and volume is known by Gay-Lussac's or Dalton's law, and is expressed by the equation

$$\frac{v \times \mathrm{P}}{v_1 \times \mathrm{P}_1} = \frac{459+t_1}{459+t} \quad \ldots\ldots\ldots\ldots (1)$$

Steam at the temperature of 212° has a density such that its volume is 1670 times that of the water which produced it; substituting these values of volume, temperature, and pressure, we get for the volume of steam from a unit of water at any other temperature,

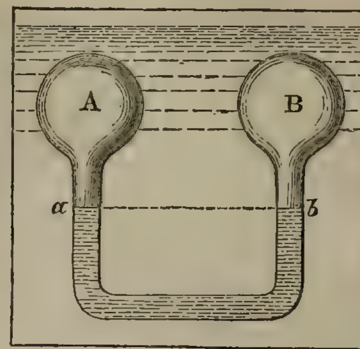
$$\mathrm{V} = \frac{1670 \times 15}{670} \times \frac{459+t}{\mathrm{P}}, \text{ or } \mathrm{V} = 37\tfrac{1}{3}\frac{459+t}{\mathrm{P}} \quad \ldots\ldots\ldots (2)$$

These are the well-known and received formulæ from which all the tables of the density of steam have hitherto been deduced, and on which calculations on the duty of steam-engines have been founded. They have not, however, up to the present time been verified by direct experiment; various speculations and theories have from time to time been propounded, as giving more accurately the density required, which, however, need the evidence and verification of direct experiment.

Great difficulties have hitherto stood in the way of making direct experiments. The temperature of saturation, or temperature at which the whole of the moisture is converted into steam, whilst no part of the steam is superheated, must be determined with the utmost accuracy, or the results are of no value.

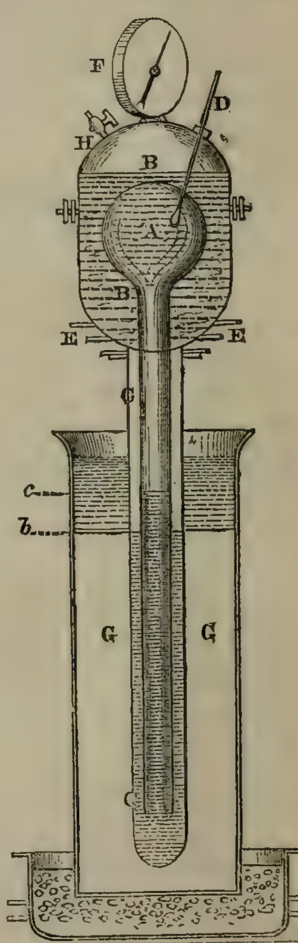
The difficulties thus resolve themselves into finding some test of sufficient accuracy and delicacy to determine the point of saturation. This has been overcome by what may be termed the saturation gauge; and it is in this that the novelty of the present experiments consists.

To illustrate the principles of the saturation gauge, suppose two globes, A and B, fig. 1, connected by a bent tube containing mercury at *a b*, and placed in a bath in which they can be raised to any required temperature. Suppose a Torricellian vacuum to have been created in each globe, and twenty grains of water to have been added to A, and thirty or forty grains to B. Now, suppose the temperature to be slowly and uniformly raised around these globes; the water in each will go on evaporating at each temperature, being filled with steam of a density corresponding to that temperature, and the density being greater as the temperature increases. At last a point will be reached at which the whole of the water in globe *a* will be converted into steam, and at this point the mercury column will rise at *a* and sink at *b*; this is the saturation test, and the cause of its action will be easily seen. So long as vaporization went on in both A and B, and the temperature was maintained uniform, each globe would contain steam of the same pressure, and the columns of mercury, *a* and *b*, would remain at the same level. But so soon as the water in A had vaporized, and the steam began to superheat, the pressure on *a* would cease to remain uniform with the pressure on *b*, and the mercury column would at once fall, and thus indicate the difference. The instantaneous change of the position of the mercury is the indication of the point at which the temperature in the bath corresponds with the saturation point of the steam in A.



To show the delicacy of this test, I may instance, that at 290° Fahrenheit, the mercury column would rise nearly two inches for every degree of temperature above the saturation point, as the increase of pressure arising from vaporization is about twelve times that arising from expansion in superheating at that point, and a similar difference exists at other temperatures.

The arrangement of the apparatus, as employed for experiment, varies according to the pressure and other circumstances of its use. Fig. 2 represents one of the arrangements which has been employed with success. It consists of a glass globe A of about seventy cubic inches capacity, in which is placed, after a Torricellian vacuum has been formed, the weighed globule of water; this is surrounded by a copper boiler B B, prolonged by a stout glass tube C C, enclosing the globe stem. This copper boiler forms the water- and steam-bath through which the globe is heated, and in fact corresponds to the second globe B in the former figure. The fluctuating mercury column, or saturation gauge, is placed at the bottom of the tube C C, and the saturation point is indicated by the rise of the inner mercury column *b*, and the fall at the same time of the outer mercury column *c*. As soon as the whole of the water in the globe A is evaporated, there is an instantaneous rise of the inner mercury column to restore the balance of pressure, and that progressively with the rise of temperature.



As an auxiliary apparatus the boiler is provided with gas-jets, E, to heat it, and with an open oil bath G to retain the glass tubes at the same temperature as the boiler, and this oil-bath is placed on a sand-bath, and also heated with gas. A thermometer D registers the temperature, and a pressure gauge F the pressure of the steam; and a blow-off cock H serves to reduce the temperature when necessary. A number of results have already been obtained, but they are not yet sufficiently advanced to be made public. The following numbers have been, however, approximately reduced from the theoretical formula above, and the experimental results may illustrate the use of this method of research. The most convenient way of expressing the density of steam, is by stating the number of volumes into which the water of which it is composed has expanded. Thus one cubic inch of water expands into about 1670 cubic inches of steam at 212° Fahr., into 882 cubic inches at 251°, and into 400 cubic inches at 304°, and so on; in this way the following numbers have been computed:—

Temperature Fahr.	Pressure in ins. of Mercury.	Volume by Experiment.
155·33	8·62	5326
159·36	9·45	4914
174·92	13·62	3433
188·30	18·36	2620
242·90	53·61	941
244·82	55·52	906
255·50	66·84	758
267·21	81·53	634
279·42	99·60	514
287·25	112·78	457
292·53	122·25	432

These determinations at pressures varying from ten to fifty lbs. above the atmosphere, uniformly show a decided deviation from the law for perfect gases, and in the direction anticipated by Professor Thomson, the density being uniformly greater than that indicated by the gaseous formula. We hope, by the time of the next meeting of the Association, to be enabled to lay before the Section a series of results which will fully determine the value of superheated steam, and its density and volume as compared with water at all pressures, varying from that of the atmosphere to 500 lbs. on the square inch.

An Experimental Illustration of the Gyroscope. By ALEXANDER GERARD.

Description of the Granite Quarries of Aberdeen and Kincardineshire. By ALEXANDER GIBB.

The author gives an account of the commencement, progress and present condition of the granite quarries of Aberdeenshire and Kincardineshire, particularly of those in the immediate neighbourhood of Aberdeen, giving an account of the chief uses to which the stone has been applied. He then proceeds to show the most economic methods of working, the drawing steam power required, the tools and number of workmen employed, with the improved methods of dressing the stone, and the various ornamental as well as useful purposes to which the stone has been applied.

On Gas Carriages for lighting Railway Carriages with Coal-gas instead of Oil. By G. HART.

The author proposes to have a reservoir of gas or a carriage constructed to carry gas and to accompany each train. He then proceeds to show how it may be conveyed to each carriage and burned in the ordinary way. Supposing a train to consist of two first, four second, and four third-class carriages, and fitted up with twenty-two Argand burners (twelve holes), the quantity of gas required for a journey of twelve hours would be 800 feet.

On Indian River Steamers and Tow Boats. By ANDREW HENDERSON.

The author gave an account of their improved construction for light draft, capability for cargo, and fittings conducive to management in shallow rapid rivers, &c., and of the practical value of the dynamometer in showing the resistance of vessels in tow, at different speeds and loads, with the result of test-trials made in England.

On a Deep-sea Pressure Gauge. By Henry Johnson.

The pressure gauge may, in its present form, be considered as a small hydraulic press; of which the ram is forced into the cylinder by the increasing pressure of the sea when sinking, and expelled by the expansion of the water in the cylinder when rising.

It consists of a small tube or cylinder having at one end a tap, through which water is admitted; the tap having in addition to the passage admitting water, a smaller passage for the escape of air. At the other end of the cylinder is a packing box, through which a round bolt or solid piston passes. A scale by the side of the piston contains the degrees of compression, and an index at the further end of the scale is drawn along the scale by the piston when forced by increasing pressure into the cylinder, and secured in its position by a spring taking hold on a toothed rack at the side of the scale, where it remains when the piston is pushed back by expansion of water in the cylinder to its former position.

The scale and index are protected by a tube screwed on to the cylinder, and the cylinder is protected from the risk of indentation by an outer tube.

In an experimental instrument the packing-box has remained water-tight under the application of a pressure of 400 lbs. to the square inch on the piston; so that the isolation may be considered sufficiently perfect, as in actual use this pressure on water in the cylinder would be counterbalanced by the external pressure of the ocean.

As the amount of friction required to obtain this isolation is considerable, and may be affected by the screwing down the packing-box, it would be desirable that after any alteration of the packing-box the instrument should be suspended, and the amount of friction ascertained, by hanging on to the piston a weight sufficient to overcome the friction.

In ascertaining the pressure of water, the amount of friction overcome should be added to the compression indicated by the index, to obtain the total amount of pressure.

Some portion of the diminution of bulk will probably be occasioned by variation of temperature, and which causes a greater variation in bulk at high temperature—

As 4000 parts of sea-water at the temperature of 86° Fahr., contracted to 3986 parts at the temperature of 65°, being $\frac{14}{4000}$ parts for 21°.
While from the temperature of 65° to 35°, the diminution to 3977 parts was only at the rate of .... $\frac{9}{4000}$ parts for 30°.

The contraction of the cylinder by variation of temperature counteracts the variation of water to a very small extent, being about $\frac{2}{4000}$th parts for 40° Fahr.

On Surface Condensation. By J. P. Joule, *LL.D., F.R.S.*

The author described the experiments he had made on this important subject. A peculiar arrangement he had introduced gave a very increased effect to a given surface. In this arrangement a copper spiral was placed in the water spaces. The spiral had the effect of giving the water a rotatory motion, and the water was thus compelled to travel over a larger surface than it otherwise would do.

On a Submarine Lamp. By Mr. Kettie.

The principle on which the lamp is constructed and depends for action, is that arising from the discrepancy of the gravity of the two columns of air necessarily engaged, viz. the column of cold for supplying combustion, and the column of heated air ejected; and in the arrangement of the tubes, advantage is taken to foster the peculiar qualities of the respective columns; thus the cold being made to descend by the larger and outer tube, whose surface is exposed to the action of the water; while the heated or centre column is placed immediately over the powerful burner of the lamp.

The lamp may be made either of a globular or cylindrical form, the bottom being made of brass, with a large screwed opening for the admission of the Argand burner used; on the top of the globe is a brass cap, into which is screwed a strong copper tube, in the centre of which is fixed another tube ¼ less in diameter, and so fixed that air may pass freely in the space between the two: the lower end of this inner tube has a trumpet-shaped termination, which enters into the globe, reaching within two inches of the top of the chimney of the Argand burner of the lamp. The upper ends of the tubes terminate in a sort of lantern-top, which is divided into a lower and upper compartment; from the lower compartment the larger tube conveys the air required by the lamp for effecting combustion; while through the upper compartment is discharged, by the inner or centre tube, the vitiated air as ejected from the lamp.

On a New Gas-burner. By the Abbé Moigno.

On an Automatic Injector for feeding Boilers, by M. Giffard. *By the* Abbé Moigno.

On a Heliço-meter, an Instrument for measuring the Thrust of the Screw Propeller. By the Abbé Moigno.

On an Application of the Moving Power arising from Tides to Manufacturing, Agricultural, and other purposes; and especially to obviate the Thames Nuisance. By the Abbé Moigno.

On the Performance of Steam-vessels. By Vice-Admiral Moorsom.

At the last Meeting of the Association, the author presented a paper in which some account was given of the 'Erminia:' he now presents further particulars of that vessel, with remarks on performance.

The performance at the measured mile, being the mean of four trips, was as follows:—

Speed of vessel, knots	6
Speed of screw, knots	6·72
Slip per cent.	10·66
Revolutions per minute	52·37
Indicator horse-power by eight diagrams	54·59
Mean pressure in boiler	51·80 lbs.
Mean pressure in cylinder	32·07 lbs.

From calculations previously made, it was anticipated that a speed of six knots would require 90 horse-power, and that the slip might be about 21 per cent. The resistance of the vessel at six knots in smooth water was first estimated by resolving the resisting surfaces into an equivalent plane surface, and deducing the specific resistance of form by an empirical application of the method of Don Gorges Juan. This gave 2763·5 lbs. It was, secondly, estimated by another empirical process, which I had found to answer within given limits of form, and was founded on Beaufoy's experiments. This gave a specific resistance of 1896 lbs. The pitch of a screw of 8 feet diameter, to produce a resultant thrust of 2763·5 lbs. at six knots, is 13·37. The pitch selected being 13 feet, the slip to balance should be 21·11 per cent. Then how comes the actual slip to be only 10·66 per cent.?

The answer to this is the key to the whole operation, and it is this:—

The *direct* thrust of the screw under the actual circumstances of the trial was 2122·7 lbs., and the *resultant* was 1896·4 lbs., and the difference of the ratios of their square roots is 10·66.

But 1896 lbs. is also the specific resistance as estimated by the second method, and as the thrust calculated by an independent process comes out the same, within half a pound, the concurrence of the two seems to establish *that* as the actual resistance at the time of the trial. Such concurrence may not, however, be held to be conclusive.

There are two modes by which these results may be tested, the one analytical, the other synthetical.

I will begin with the first, and employ the other in elucidation. The effective power, or total resistance, from the actual power of 54·59 horse-power, or 1801470 lbs. at six knots, is 2961·67 lbs., which is thus distributed:—

	lbs.
Specific resistance	1896
Equivalent of slip	315·67
Resultant of absorbed power	750
Total	2961·67

I have in this analysis, as in my former paper, classed under the general term "equivalent of slip," two distinct elements, which I must now separate.

The first is that portion of the effective power which overcomes the resistance of the water to the rotation of the blades of the screw, and which is sometimes called "lateral slip." The second is that portion of the effective power which is employed in pushing back the water to obtain a fulcrum.

	lbs.
The first is	204
The second is	111·67
Making together the	315·67

The absorbed power is composed of—1st, the friction of moving the machinery; 2nd, the additional friction of the load; 3rd, the back pressure (as we are dealing with a non-condensing engine) from the blast-pipes.

	lbs.
For the first we have	136·92
For the second	189·60
For the third	423·48
Making the total of	750

In order to give a clearer view of these elements, I will reverse them, and show the corresponding pressure upon the piston:—

	lbs.	Pressure on piston. lbs. per square inch.
Back-pressure	423·48	4·64
Additional friction of load	189·60	2·07
Moving friction	136·92	1·50
Resistance of water to rotation of blades	204·00	2·23
Slip in terms of effective power	111·67	1·22
Specific resistance of vessel	1896·00	20·78
Making the totals of	2961·67 and	32·44

The pressure on the piston by the diagrams is 32·07 lbs., showing a difference of 0·37, which may be considered near enough.

Now, if it be said that this is an arbitrary classification not resting upon known data, I reply, not altogether so. I have lying before me diagrams of back-pressure from 3·45 lbs. per square inch on the piston, moving at 236 feet per minute, with a mean pressure of 67·56 lbs. to 12·3 lbs. per square inch on the piston, moving at 569 feet per minute, with a mean pressure of 65 lbs., the diameters of blast-pipes varying from $4\frac{3}{4}$ to $4\frac{1}{4}$ inches, and the relations of steam ports from $14\times1\frac{3}{8}$ inches to $12\frac{1}{2}\times1\frac{1}{2}$ inches of area.

The 'Erminia's' blast-pipes were 4 inches in diameter, the steam ports $12\times1\frac{1}{4}$, and the speed of piston 157 feet per minute, with a pressure of 32·07 lbs. per square inch in the cylinder.

The back-pressure of 4·64 lbs. which results from the analysis is therefore probable, and consistent with experience.

The next element of additional friction arising from the load, viz. 2·07 lbs. per square inch, is calculated upon the specific resistance of 1896 lbs., and may be disputed, because there are no satisfactory experiments on the subject. It is an estimate, and may be in excess.

The next element of the pressure to move the machinery, viz. 1·5 lb. per square inch, is a little over the mean of certain trials made by my direction, of which the diagrams are before me, the maximum being 1·63 lb., and the minimum 1·14 lb.

To this no reasonable exception can be taken.

The resistance to the rotation of the blades, 2·23 lbs., is calculated upon the basis of such experiments as I have access to on the friction of water on iron, and on the effective periphery of the screw.

For this element, also, more precise experiments are needed, and it must be considered an estimate only.

The slip, 1·22 lb., requires no elucidation, except that it is what remains after deducting the effect of the resistance to the rotation of the blades. The specific resistance, equal to 20·78 lbs. per square inch on the piston, or in the convertible terms of 1896 lbs. of effective power, may therefore be dealt with as a probable result, and if so, the power of the screw is needlessly in excess of any resistance the 'Erminia' is likely to offer; and I have explained why it is so, viz. because it was designed to produce a thrust at about 21 per cent. of slip, about 50 per cent. greater than the resistance of the vessel *in smooth water*, which resistance, viz. 2763·5 lbs., turns out to be 45 per cent. greater than the actual resistance.

Hence the screw is *capable* of a thrust nearly double of what the 'Erminia' requires in smooth water.

What, then, is the most suitable size and proportion of screw for this yacht?

I believe it will be found that the diameter should be as large as is consistent with its being *sufficiently* immersed, but no larger; and that the pitch should then be such as to produce a thrust to balance the resistance under ordinary conditions at sea with a moderate slip.

If the screw be 8 feet diameter, then, to produce a thrust of 1896 lbs. at 6 knots, the pitch must be 9·18 feet, and the slip about 13½ per cent.

But, under ordinary conditions at sea, the resistance will be increased, and it is expedient to have a coarser pitch, in order that the thrust may balance the resistance without excessive slip.

If we assume the specific resistance at a mean between the two calculated results before described, or 2329·75 lbs., the pitch must be 11·27 feet; and when the thrust works up to this resistance, the slip will be about 20 per cent.

The next vessel to which I must invite attention is the yacht of the Duke of Sutherland, mentioned in my former paper.

Full particulars of the performance of the 'Undine,' at the measured mile in the Thames, on the 6th July, 1858, in Loch-Lochy on the 27th October, and in Loch-Ness on the preceding day, have been laid before the "Steam-ship Performance Committee" by Mr. M'Connell.

The particulars of this vessel are:—

Length of water-line		125 feet.
Breadth, extreme		25 feet.
Draught of water	F.	8·6 inch.
	A.	11·10 inch.
Displacement about		294 tons.
Area of greatest transverse section		154·33 sq. feet.
Diameter of screw		7·10 inch.
Pitch, &c.		11·4 inch.
Length		1·4 inch.
Extreme breadth of blade		2·8 inch.
Area of blade about		13 sq. feet.
Immersion of periphery		1·8 inch.
Diameter of cylinder		0·24 inch.
Stroke		0·15 inch.
Area of fire-grate		45 sq. feet.
Plate surface		206 sq. feet.
Tubes		820 sq. feet.

The performance on the 6th of July was:—

Speed of vessel	9·26 knots.
Screw	11·29 knots.
Slip per cent.	17·91 knots.
Revolutions per minute	101·74 knots.
Indicator horse-power by diagrams	157·09 knots.
	lbs. per sq. in.
Mean pressure in cylinder	12·28
Mean pressure from vacuum	10·70
Total pressure	22·98
Mean pressure in boiler	15·80

Now, the specific resistance of the 'Undine' at 9·26 knots, estimated as the 'Erminia's,' by the empirical rule founded on Beaufoy's experiments, is 3809·4 lbs.

By the synthetical method it is as under, viz.—

	lbs. per square inch.	lbs. in terms of effective power.
Moving friction	1·40	342·89
Additional friction for load	1·55	380·94
Resistance to rotation of blades	2·37	582·50
Slip in terms of effective power	1·65	405·10
Total, less specific resistance	6·97	1711·43
Total pressure and effective power	22·51	5517
Specific resistance	15·54	3805·57

The difference between 3805·57 and 3809·4 is not material in estimates such as this.

It will be seen, also, that there is a difference of 0·47 lb. per square inch in the aggregate pressure as compared with that given by the diagrams.

So far the two methods are in harmony; but now I have to show a screw that is not so tractable.

The *direct* thrust at 11·29 knots is 7469·3 lbs., and the slip being 17·91 per cent., the *resultant* is 5022·3 lbs., or more than 31 per cent. greater than the resistance of the vessel.

This, however, cannot be so, and the apparent excess must be accounted for.

I have already said that the screw must be *sufficiently* immersed, in order that its thrust may be that which is due to its diameter and pitch.

What is *sufficient* is yet an open question. The 'Erminia's' was 2 feet 6 inches, the 'Undine's' only 1 foot 8 inches.

I believe this to be the explanation of the anomaly.

The apparent thrust of 5022·3 lbs. was really an effective thrust of only 3805·57 lbs. in consequence of the rotation of the blade breaking up the surface of the water.

This screw would produce, if sufficiently immersed, a resultant thrust of 3805·57 lbs. at 9·26 knots, with a slip of 10·32, say $10\frac{1}{2}$ per cent.

The actual slip was 17·91 per cent.

We have now reached one of the most interesting of the investigations, which, in my former memoranda, I pointed out as worthy of the attention of the British Association.

This is an investigation by experiment not difficult to accomplish, and yet I conclude it has not had the consideration of the naval authorities, as they continue to give screws to their ships, which are only immersed about one-fourth to one-eighth of their diameter, whereas the 'Erminia's' was immersed about one-third, while the 'Undine's' was about one-fifth. The due proportion of immersion will, I believe, be found to depend somewhat on the speed of rotation.

On the Manœuvring of Screw Vessels.
By Admiral PARIS, *C.B., of the Imperial French Navy.*

The propelling properties of the paddles and of the screw are very different according to the form, mode of acting, and especially the position of the propellers in the ship.

The paddle acts at the surface of the water and pushes it in the direction of the keel, when working ahead. Thus the current produced by the resistance of the water is useless to the rudder, because it acts only on the upper part, where it presents no flat surface.

The screw acts on the water by a twisted surface, which, instead of pushing back the water in the direction of the keel gives it a whirling motion and projects it abaft in the shape of a cone, producing a current in the same way that the paddle-wheels do; but being below the surface of the water, and the propeller being just ahead of the rudder, the latter receives the impulse of this artificial current which acts before the ship has moved, because the inertia makes her resist, for a few minutes, the impulse of the propeller.

Hence a principle is deducible, viz. that the paddle-wheel ship cannot steer *without* moving, and that, on the other hand, screw ships steer *before* moving, and that even long after the propeller is at work, if any object offers resistance to its translating action.

Another difference arises from the action of the screw, because its blades are oblique to the length of the ship, and all of them are pushing the stern not only ahead or astern, but also sideways, so that if the water were equally resistant close to the surface and below it, the equilibrium of both vertical blades would make the screw act equally throughout its path. But this is not the case: the water being more resistant as the depth increases, the lower blade finds more difficulty in moving than the upper one; and the stern being acted on sideways by this difference in the resistance, the ship will not move straight ahead; and if the rudder does not balance this effect, she will always deviate to the same side when going astern. This effect will naturally be more or less energetic according to the immersion of the screw and the relative pitch; for if the screw shaft were at the level of the sea, and the pitch infinite—that is, should the blade be in the place of the axis, the stern will only be deviated and not propelled; consequently, in the actual state of things, the side action of the screw on the stern is a mixture of the propelling and of the lateral effect: this cannot be avoided, and is only lessened by a deeper immersion, or reduction of pitch; and the direction is according to the side of the thread; so that a right-handed thread deviates the ship to larboard when going ahead, and to starboard when going astern; it is the reverse for a left-handed thread.

From this it would appear, at first sight, that the paddle acts much better in making a ship steer well than the screw, and that the disturbances of the screw on the true shipway present obstacles to the management of the ship. But it is not so; and these properties of the screw can be used in such a way as to make various manœuvres, impossible with paddles.

Thus if a ship is required to turn short at the moment before leaving her anchorage, the paddle vessel will want ropes, or at least sails, if the direction of the wind permits, and her propeller will be used only to resist the wind or to act in the direction of the keel. The screw, however, enables her to turn round on the same place when in a calm; for if the ship has a little more cable out than the depth of water, so that the anchor will still offer a small resistance, and she moves her screw slowly, the anchor holding on, prevents the ship from going ahead, whilst at the same time the screw throws water on the rudder and makes it steer the ship as though she were under way: this is well known; and many vessels are handled in this way to give them the proper direction without moving ahead; and when at the proper point of the compass, they weigh anchor and go ahead.

If she is not at anchor, a screw ship can also turn herself by her own inertia: thus, if the screw backs, the ship will begin to turn her head to starboard, and when she has gone about half her length, reverse the engines, and work them quicker with the helm a-port—the ship will go ahead but turn on the same side; so by repeating several times the same reversing operation, the turn of the horizon will be made much more quickly than would at first be supposed, and the space required to turn in may be lessened at pleasure by shortening each period of the operation.

If there is any breeze the sails can be employed to accelerate the evolution, either by their oblique action, as with the gib or the mizen sail, or by being used only to resist the impulse of the propeller, in order to give it a more energetic oblique action. So with the wind ahead, and the main-top sail bearing on the mast, a stronger current is produced on the rudder's surface; and when the wind is abaft, the same sail being full, a greater speed may be given to the screw in order to make its oblique action stronger and let the ship turn quicker. In the intermediate positions between the head and the back wind, the main-top sail is directed in such a manner that it is always acting against the screw. These manœuvres of screw ships have been executed several times, and have enabled ships to enter crowded roads and to pass through spaces where ordinarily it would have been impossible to pass.

Ships are sometimes required to remain in one position without dropping anchor; with sails, as with paddles, there is always lee way, and the ship cannot keep the same position unless with a beam wind. It is also difficult to take another ship in tow, as large ships want much time to send their heavy tow ropes on board, and have generally to drop anchor and weigh again when the second one is in tow; this is a very long operation, and may be readily avoided by making use of the properties of the screw when the wind is ahead or astern. Suppose, for instance, that a ship is intending to take in tow another lying at anchor. She will sheet and hoist her mizen-top sail and gallant sail according to the wind, and place herself a short distance ahead of the other, and make her engine work slowly. Thus as the backing force of the mizen sails would be compensated by the heading force of the propeller, the ship acted on by these two equalized and opposite forces will be motionless, but she will steer as well as if making way, on account of the artificial current before alluded to, and may change her direction or remain quite motionless, regardless of the direction of her head, as long as may be desired. This I have done several times when ordered to take ships in tow, and once remained nearly twenty minutes in almost exactly the same position.

This combination of both propelling powers, the sails and the screw, may also be used to maintain the ships with an oblique direction of the wind, two or three points, for example, by bracing properly the mizen-top sail; but when there is a slight lee way, and if the wind blows in the direction of the beam, it is the common condition of sailing or paddle vessels standing on.

Condensed Abstract of a First Set of Experiments, by Messrs. Robert Napier *and* Sons, *on the Strength of Wrought Iron and Steel. By* W. J. Macquorn Rankine, *C.E., LL.D., F.R.SS. L. & E.*

The experiments to which this abstract relates form the first set of a long series now in progress by Messrs. Robert Napier and Sons, the details being conducted by their assistant, Mr. Kirkcaldy. The whole results are now in the course of being printed *in extenso*, for publication in the 'Transactions of the Institution of Engineers in Scotland' for the session 1858–59*.

The present abstract is all that it has been found practicable to prepare in time for the meeting of the British Association; and, notwithstanding its brevity and extreme condensation, it is believed that the results which it shows will be found of interest and importance. It gives the tenacity and the ultimate extension, when on the point of being torn asunder, of the *strongest* and the *weakest* kinds of iron and steel from each of the districts mentioned. Each result is the mean of four experiments at least, and sometimes of many more.

The detailed tables, now being printed, will show many more particulars, and especially the contraction of the bars in transverse area along their length generally, owing to "drawing out," and the still greater contraction at the point of fracture. The experiments now complete were all made with loads applied gradually. Experiments on the effect of suddenly applied loads are in progress.

Iron Bars.

	Tenacity in lbs. per sq. inch.	Ultimate extension in decimals of length.
Yorkshire: strongest	62886	0·256
,, weakest	60075	0·205
,, (forged)	66392	0·202

* This volume of 'Transactions' has since been published.

	Tenacity in lbs. per sq. inch.	Ultimate extension in decimals of length.
Staffordshire: strongest	62231	0·222
„ weakest	56715	0·225
West of Scotland: strongest	64795	0·173
„ weakest	56655	0·191
Sweden: strongest	48232	0·264
„ weakest	47855	0·278
Russia: strongest	56805	0·153
„ weakest	49564	0·133

IRON PLATES.

	Tenacity in lbs. per sq. inch.	Ultimate extension in decimals of length.
Yorkshire: strongest lengthwise	56005	0·141
„ weakest lengthwise	52000	0·131
„ strongest crosswise	50515	0·093
„ weakest crosswise	46221	0·076

Note.—The strongest lengthwise is the weakest crosswise, and *vice versâ.*

STEEL BARS.

	Tenacity in lbs. per sq. inch.	Ultimate extension in decimals of length.
Steel for tools, rivets, &c.: strongest	132909	0·054
„ weakest	101151	0·108
Steel for other purposes: strongest	92015	0·153
„ weakest	71486	

STEEL PLATES.

	Tenacity in lbs. per sq. inch.	Ultimate extension in decimals of length.
Strongest lengthwise	94289	0·0571
Weakest lengthwise	75594	0·1982
Strongest crosswise	96308	0·0964
Weakest crosswise	69016	0·1964

Note.—The strongest and weakest lengthwise are also respectively the strongest and weakest crosswise.

On the Comparative Value of Propellers. *By* JOHN ROBB.

Robertson's *Patent Chain Propeller.* *By* PETER SPENCE.

The peculiar principle of Mr. Robertson's invention is, that he applies the power by dragging the vessel from a fixed point; and its great ingenuity is, that the fixed point is at the same time a moveable one, a constantly fixed point in relation to the power exerted by the engine in propelling the vessel, and a constantly changing point in relation to the course on which the vessel is being propelled. The construction of the propelling apparatus is as follows:—At or near the bows of a boat, say 70 feet long, is placed a steam-engine, the main shaft of which crosses the bows of the vessel at or about the level of the deck; a fixed pulley is attached to each end of this shaft, these pulleys projecting over the sides of the vessel; they are three feet or more in diameter, and on their periphery have a hollow or groove to receive the chains which are to run over them; they are also so constructed as to take a firm hold of the chains as the power is exerted in dragging the chains over the pulleys. On the other or the stern end of the boat are two pulleys, also projected over, one on each side; these are loose, so that the chains merely run over them. Friction rollers are also placed along each side of the vessel, to carry the chains as they pass from the stern to the bows of the vessel; the chains, which are endless, pass or are dragged over fixed pulleys at the bow of the vessel; and falling down, lie along the bottom of the canal, and thus become the fixed point or lineal anchor on which the power acts; the action of the engine in dragging the chain over the loose and fixed pulleys being necessarily to drag or propel the boat forward.

Every yard of the chain passed over the pulleys representing a yard of space that the boat has progressed in her course—the fixed point or length of chain lying at the bottom of the canal still remaining the same, what is taken up at the stern being replaced by exactly the same length deposited at the bows. The speed of the vessel is thus exactly equivalent to the speed and size of the driving pulleys, unless, indeed, there should be any slip of the chain in passing over them, and this in practice is easily prevented, and is again exactly measured by the velocity of the chain, unless there should be a slip of the chain along the whole length over the bottom of the canal, and this, of course, is a mere matter of the weight of the chain.

On the Nomenclature of Metrical Measures of Length. By G. Johstone Stoney, *M.A., M.R.I.A.*

In this paper many circumstances were pointed out which render the French names of decimetre, centimetre, and millimetre unsuited to this country. They are foreign to the genius of our language, which delights in short pithy words; the information they convey is useless, as the fact that each measure is one-tenth of that above it is one of that class which it is impossible to forget, and they fail in several common requisites of a good nomenclature.

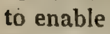
Names of measures for ordinary use should, if possible, be monosyllables; for the convenience of reference they should begin with different initial letters; they should so wholly differ in sound that even when imperfectly pronounced they could not be mistaken for one another, and they should convey some information which would facilitate the use of the measures by those who are unfamiliar with them.

To combine these advantages, it was suggested that *hand* or hand-breadth should be used as the English equivalent for decimetre, *nail* or nail-breadth for centimetre, and *line* for millimetre. The author stated that he had had abundant experience of the assistance afforded to beginners by these names, from their promptly suggesting, without any mental effort, the *absolute length* of each measure.

Attention was also directed to the importance of giving a distinct name to the tenth part of the line or millimetre, in order to discourage the use of binary subdivisions: *mite* was suggested as a suitable name.

The paper closed by urging that the use of foot-rules graduated along one side to metrical measures should in every possible way be encouraged.

On the true Action of what are called Heat-diffusers. By A. Taylor.

Gases do not *radiate* the heat which they contain; so that the only mode in which a gas can communicate its heat to a surface is by contact or conduction: this in the present practice is the only mode in which the heating surfaces of a boiler which are not exposed to the radiation of the fire or flame can abstract heat from the products of combustion: but if in a flue or tube a solid body be introduced, it will become heated by contact with the gases, and will radiate the heat thus received to the sides of the flue. It will be admitted that the amount of heat thus conveyed to the water may be very important, when it is considered that the temperature of the gases in the tubes of a boiler at five or six inches from the fire-box tube plate is about 800° Fahr., and that these radiators will consequently have a temperature of several hundred degrees above that of the surfaces in contact with the water in the boiler, and that a very active radiation must consequently take place from one to the other. This principle once established, the modes of application in practice are of course endless. It is, however, unnecessary to make the radiating surfaces of such a form as to impede the draught. I would rather choose the form which would give the greatest amount of radiating surface and offer the least impediment to the free passage of the products of combustion through the tubes. Perhaps as effective a form as any for placing in the tubes of boilers would be a simple straight band of metal, or a wider band bent in the direction of its breadth at an angle of 60° thus—

In the case of marine boilers, they should be made to draw out easily to enable the tubes to be swept.

Description of various Models of Fire Escapes, Boat-lowering Apparatus, &c. By Adam Topp.

On a Mode for Suspending, Disconnecting, and Hoisting Boats attached to Sailing Ships and Steamers at Sea. *By* E. A. Wood.

APPENDIX.

Mathematics and Physics.

On a remarkable specimen of Chalcedony, belonging to Miss Campbell, *and exhibiting a perfectly distinct and well-drawn landscape.* *By* Sir David Brewster, *K.H., LL.D., F.R.S.*

Sir David Brewster, who had examined the specimen, ascertained that the landscape was not between two plates subsequently united, but was in the interior of a solid piece of chalcedony.

He stated that chalcedony was porous, and that the landscape was drawn by a solution of nitrate of silver, which entered the pores of the mineral.

Sir David Brewster stated that above thirty years ago he had examined a similar specimen, belonging to the late Mr. Gilbert Innes of Stow, who had paid a large price for it. Having no doubt that the figure of a cock which it contained was drawn by nitrate of silver, introduced into the pores of the mineral, he induced the late Mr. Somerville, a lapidary in Edinburgh, to make the experiment; and he succeeded in introducing the figure of a dog into the interior of the mineral.

The curious fact, however, displayed by the specimen now exhibited to the Section, is that the landscape had entirely disappeared after being kept four years in the dark.

When the specimen was received yesterday from Miss Campbell, the landscape was wholly obliterated; but after the exposure of an hour this morning, it reappeared in the distinctest manner, as may be seen by looking at it against a white ground.

It is of importance to remark that the figure of the cock in Mr. Innes's specimen which was very strong in its tint, had never been seen either to disappear or to diminish in its tints.

On the Connexion between the Solar Spots and Magnetic Disturbances. *By* Sir David Brewster, *K.H., LL.D., F.R.S.*

On a Method of reducing Observations of Underground Temperatures. *By* J. D. Everett, *Professor of Mathematics in King's College, Windsor, Nova Scotia.*

The paper commenced by an acknowledgment of obligation to Prof. W. Thomson, LL.D., of Glasgow, for a knowledge of the principle on which the method is based. The objects sought to be attained are,—1st, to express the temperature in terms of the time of year (on the average of a number of years); and 2nd, to deduce the conducting power of the soil. The paper contained an application of the method to temperatures observed during the seventeen years 1838–54, at the Royal Edinburgh Observatory. The underground thermometers at this Observatory are four in number, and are at depths of 3, 6, 12 and 24 French feet respectively. Their average temperatures for each calendar month were—

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
At 3 feet..	40°·57	39°·64	40°·31	42°·45	45°·87	49°·86	52°·70	53°·82	52°·75	49°·15	45°·52	42°·62
At 6 feet..	43·59	42·35	42·00	42·79	44·65	47·23	49·71	51·31	51·54	50·11	47·81	45·48
At 12 feet..	46·84	45·82	45·06	44·68	44·88	45·63	46·84	48·07	48·96	49·27	49·02	47·94
At 24 feet..	47·77	47·63	47·39	47·08	46·79	46·59	46·55	46·69	46·97	47·31	47·61	47·79

From these data the temperature of any one of the thermometers may be expressed in the form

$$v = A_0 + A_1 \cos 2\pi\frac{t}{T} + B_1 \sin 2\pi\frac{t}{T} + A_2 \cos 4\pi\frac{t}{T} + B_2 \sin 4\pi\frac{t}{T} + \&c., \quad . \quad (1)$$

where v is the temperature at the time t reckoned from the middle of January, T is the periodic time (a year), and the constants A_0, A_1, A_2, B_1, B_2 are found in the manner shown below:—

I. Temperatures of first six months.	II. Temperatures of last six months.	III. I.−II.	IV. Last two numbers in III. reversed	III.−IV.	Multipliers.	Products.	III.+IV.	Multipliers.	Products.
40°·57	52°·70	−12°·13	°	−12°·13	S_3	−12°·13	−12°·13	0	°·00
39·64	53·82	−14·18	+7·24	−21·42	S_2	−18·55	− 6·94	S_1	− 3·47
40·31	52·75	−12·44	+0·35	−12·79	S_1	− 6·39	−12·09	S_2	−10·47
42·45	49·15	− 6·70		− 6·70	S_0	·00	− 6·70	1	− 6·70
45·87	45·52	+ 0·35							
49·86	42·62	+ 7·24			6)	−37·07		6)	−20·64
					$A_1=$	− 6·18		$B_1=$	− 3·44

V. First half of (I.+II.)	VI. Last half of (I.+II.)	V.−VI.	Multipliers.	Products.	V.−VI. (again)	Multipliers.	Products.
93°·27	91°·60	+1°·67	1	+1°·67	+1°·67	0	°·00
93·46	91·39	+2·07	S_1	+1·035	+2·07	S_2	+2·295
93·06	92·48	+0·58	$-S_1$	−0·290	+0·58		
			6)	+2·415		6)	+2·295
			$A_2=$	+ ·4025		$B_2=$	+ ·3825

A_0=mean of all the Nos. in I. and II.=46·27.

The symbols S_0, S_1, S_2, S_3 denote the sines of 0°, 30°, 60°, and 90° respectively.

The following Table exhibits the values of the coefficients found as above:—

Thermometer.	A_0.	A_1	B_1.	A_2.	B_2.
3 feet	46°·27	−6°·18	−3°·44	+°·4025	+°·3825
6 feet	46·55	−3·10	−3·65	+·120	+·293
12 feet	46·92	+0·03	−2·31	−·0833	+·0635
24 feet	47·18	+0·615	−0·118	−·0167	−·0144

Expression (1) is now to be converted into the form

$$v = A_0 + P_1 \sin\left(2\pi\frac{t}{T} + E_1\right) + P_2 \sin\left(4\pi\frac{t}{T} + E_2\right) + \&c., \quad . \quad . \quad . \quad (2)$$

by applying the equations

$$\frac{A_n}{B_n} = \tan E_n, \qquad \sqrt{A_n^2 + B_n^2} = P_n;$$

and the resulting values of the new constants are—

Thermometer.	P_1.	P_2.	E_1.	E_2.
3 feet	$7^\circ\cdot07$	$^\circ\cdot56$	$240^\circ\ 54'$	$46^\circ\ 27\frac{1}{2}'$
6 feet	4·79	·32	220 20	22 16
12 feet	2·31	·10	179 15	− 52 41
24 feet	·63	·02	100 52	−130 46

An inspection of equation (2) shows—

1st. That the range of any term $P_n \sin\left(2_n\pi\frac{t}{T}+E_n\right)$ is $2P_n$, the maximum value being $+P_n$, and the minimum $-P_n$.

2nd. That the term goes through its cycle of values in the $\frac{1}{n}$th part of a year.

3rd. That any decrease in the value of E_n amounts to a retardation of the epochs of maxima and minima.

Since the value of any term can never exceed that of its coefficient P_n, it is obvious that when P_n is very small the term may be neglected. Generally speaking P_n becomes rapidly smaller as we advance in the series, and for most purposes all terms after that containing P_2 may be neglected.

The conducting power of the soil can be found in the following manner. Let x denote the difference in depth of any two of the thermometers; and let $\Delta . E_n$ and $\Delta . \log_e . P_n$ respectively denote the amounts by which the values of E_n (in circular measure) and $\log_e P_n$, for the upper thermometer, exceed the values of the same functions for the lower. Then will

$$\frac{\Delta . E_n}{x}=\frac{\Delta . \log_e P_n}{x}=\sqrt{\frac{n\pi c}{Tk}},$$

k being the conductivity of the soil and c its capacity for heat.

The values of E_1 and E_2 in circular measure, and of $\log_e P_1$, $\log_e P_2$, are as follow:—

Thermometer.	E_1.	E_2.	$\log_e P_1$.	$\log_e P_2$.
3 feet	$4^\circ\cdot20$	$+^\circ\cdot81$	$1^\circ\cdot95$	$-^\circ\cdot59$
6 feet	3·85	+ ·39	1·56	−1·15
12 feet	3·15	− ·92	·84	−2·25
24 feet	1·76	−2·28	− ·47	−3·81

And the results of comparing the thermometers two and two in every possible way are, for the term in P_1,—

Thermometers compared.	$\Delta . E_1$.	x.	$\sqrt{\frac{\pi c}{Tk}}$.	$\Delta . \log_e P_1$.	x.	$\sqrt{\frac{\pi c}{Tk}}$.
3 feet and 6 feet...	$^\circ\cdot35$	3°	$^\circ\cdot117$	$^\circ\cdot39$	3°	$^\circ\cdot130$
3 feet and 12 feet...	1·05	9	·117	1·11	9	·123
3 feet and 24 feet...	2·44	21	·116	2·42	21	·115
6 feet and 12 feet...	·70	6	·117	·72	6	·120
6 feet and 24 feet...	2·09	18	·116	2·03	18	·113
12 feet and 24 feet...	1·39	12	·116	1·31	12	·109
Means	......	...	·1165	....	...	·1183

The term in P_2, treated in like manner, gives ·113 and ·116 as the values of $\sqrt{\frac{\pi c}{Tk}}$. The true value is probably about ·117, and the value of the ratio $\frac{k}{c}$ can be found from this by an obvious arithmetical process.

On an Application of Quaternions to the Geometry of Fresnel's *Wave-surface.* *By* Sir William Rowan Hamilton, *LL.D. &c.*

Abstract of Formulæ.

$\rho =$ vector of ray-velocity; $\mu =$ index-vector, or vector of wave-slowness; $S\mu\rho = -1$, $S\mu\delta\rho = 0$, $S\rho\delta\mu = 0$ (equations of reciprocity); $\delta\rho =$ vector of displacement, or of vibration; $\phi^{-1}\delta\rho =$ vector of elasticity, or of total resulting force of restitution (ϕ being the same symbol of operation as in the Seventh Lecture on Quaternions, by the present author); $\mu^{-2}\delta\rho =$ a vector, representing the tangential component of elasticity; $\therefore (\phi^{-1} - \mu^{-2})\delta\rho =$ normal component of elasticity $= \mu^{-1}\delta m$, δm being a scalar; $\therefore \delta\rho = (\phi^{-1} - \mu^{-2})^{-1}\mu^{-1}\delta m$, and $S\mu^{-1}\delta\rho = 0$; $\therefore$ the formula,

$$0 = S\mu^{-1}(\phi^{-1} - \mu^{-2})^{-1}\mu^{-1}, \quad \dots \dots \quad \text{(a)}$$

is a *symbolical form of the equation of the index-surface,* or of the surface of wave-slowness, to which the wave itself is *reciprocal.* Hence, by the equations of reciprocity given above, or simply by changing μ to ρ, and to ϕ ϕ^{-1}, we obtain the formula,

$$0 = S\rho^{-1}(\phi - \rho^{-2})^{-1}\rho^{-1}, \quad \dots \dots \quad \text{(b)}$$

as a *symbolical form of the equation of Fresnel's wave.*

To *interpret* this equation, or to deduce from it a *geometrical construction,* we may observe that the formula (assigned in the Seventh Lecture),

$$1 = S\rho\phi\rho, \quad \dots \dots \quad \text{(c)}$$

is the equation of a certain *auxiliary ellipsoid*; and that

$$\sigma = \rho^{-1}V\rho\phi\rho = \phi\rho - \rho^{-1} = (\phi - \rho^{-2})\rho$$

is a vector perpendicular to the plane of that diametral section whereof ρ is a semi-axis. Hence

$$0 = S\sigma\rho = S\sigma(\phi - \rho^{-2})^{-1}\sigma$$

is an equation which determines the two values of the square $(-\rho^2)$ of the length of a semiaxis of the diametral section made by a plane perpendicular to σ; and if $T\sigma = T\rho$, so that the normal σ to the plane of the section is made equal in length to one or other of the two semiaxes, then

$$0 = S\sigma(\phi - \sigma^{-2})^{-1}\sigma. \quad \dots \dots \quad \text{(d)}$$

But this is just the equation (b) of the wave, with σ written instead of ρ. Hence, then, is at once derived the celebrated construction of Fresnel, namely, that "the wave surface (for a biaxal crystal) is the locus of the extremities of normals to the diametral sections of an ellipsoid, each normal having the length of one of the semi-axes of that section."

On certain Properties of the Powers of Numbers. *By* J. Pope Hennessy, *M.P.*

On Gutta Percha as an Insulator at various Temperatures. *By* Fleeming Jenkin.

This paper contained an abstract of experiments, made for Messrs. R. S. Newall and Co., to determine the absolute resistance of gutta percha, and the effect of temperature on that resistance.

The absolute resistance of gutta percha was calculated by the author from tests on long submarine cables: the variation of resistance due to varying temperature was obtained from observations on short lengths of cable immersed in water at various temperatures.

The gutta percha covering the long cables was used in alternate layers, with a varnish known as Chatterton's compound.

The short lengths, tested in water of various temperatures, were three in number, and will be called numbers 1, 2, and 3. The length of each was one knot. The diameter of the gutta percha, in numbers 1 and 2, was 0·3 in., covering a single copper wire of 0·06 in. diameter.

No. 3 was a knot of the Red Sea core: the diameter of the gutta percha was 0·34 in., covering a copper strand formed of seven wires, each 0·038 in. diameter.

The coils were placed in a felted tub, and were covered with water of the desired temperature for several hours before the experiments were made.

The loss or escape of electricity was measured on a delicate zinc galvanometer.

Separate tests were made with the positive and negative poles, and at each test five readings were taken; the first one minute after the application of the current, the others at successive intervals of one minute.

On coil No. 1, covered with Chatterton's compound and gutta percha, there was a marked difference between the tests made with positive and negative currents; whereas in coil No. 2, covered with pure gutta percha, there was no difference between those tests from 50° to 75° Fahrenheit.

In both coils and at all temperatures the loss decreased rapidly during the first two minutes after application of the battery; this decrease continued till the fifth minute, when a minimum was nearly attained. This effect in coil No. 2 was regular, and between 50° and 80° Fahrenheit was not affected by a change in the size of the current.

In coil No. 1 the decrease of loss was regular and nearly constant when the zinc pole was connected with the coil; whereas irregular results were obtained when the copper pole of the battery was so connected.

The extra resistance or decrease of loss was still more marked in coil No. 3, where the gutta percha is of larger diameter. In this coil the loss decreased 30 per cent. in the interval separating the first and fifth minute.

The same phenomenon (decrease of loss) was observed on the long cables.

The insulation of a sound gutta percha covered wire is therefore improved by the application of either a positive or a negative current. It also appears that it is most necessary, in testing the insulation of a cable, to record the time separating the observation and the first application of the battery.

The phenomenon of decreased loss or extra resistance is observed, whether the cable is dry or immersed in water.

The annexed Tables I. and II., showing the relative loss from the two coils at different temperatures, give the result of the experiments as deduced from curves which result from the observations after all due corrections have been made for loss on connexions and varying electromotive force.

The numbers in the Tables give no absolute measurement, but only the relative loss at the various temperatures.

At 65° the two coils 1 and 2 test much alike. At high temperatures pure gutta percha rapidly deteriorates; at low temperatures it has the advantage.

The irregularity of the copper tests of No. 1 lead to some suspicion of a chemical action between the various substances in contact.

Table No. III. contains the results of similar experiments on coil 3.

The absolute resistance of the insulating cover was obtained by comparison of the current flowing through the gutta percha, and that flowing through a coil of known resistance, or through the copper core itself. The actual resistance of the insulating cover being known, this formula, due to Professor Thomson, was used to determine the specific resistance, or the resistance of a cubic foot: $x = \mathrm{R}\dfrac{2\pi l}{\log \frac{a}{b}}$, where R = resistance of cylindrical coating, l = length of wire tested, $\frac{a}{b}$ = ratio of the diameter of the copper core to that of the gutta percha covering, x = specific resistance of the material.

The specific resistance of gutta percha of the Red Sea core, at 6°Fahrenheit, calculated from daily tests of the Red Sea cables, was found to be 205×10^{18} absolute British units.

Owing to the influence of the phenomenon of extra resistance described above, this number does not express a well-defined resistance such as that of a metal, but gives an approximate resistance at about thirty seconds after application of the battery.

The corresponding specific resistance at 60° of No. 1 coil was found to be 195×10^{18}.

The specific resistance of No. 2 coil at the same temperature was 202×10^{18}.

The resistance at other temperatures, or after longer application of the battery, is inversely proportional to the numbers given in the three Tables, and representing the relative loss.

The employment of Chatterton's compound in different proportions from those used in the above coils, would necessitate fresh experiments in each case to determine the effect of temperature.

Since writing the above paper a detailed account of the experiments, and the results of more extended calculations, have been communicated to the Royal Society in a paper read March 22, 1860.

Table I.

Temperature.	Loss after first minute.		Loss after fifth minute.	
	Zinc to coil.	Copper to coil.	Zinc to coil.	Copper to coil.
50°	125	110	100	92
55	136¼	122	116½	100
60	147	144	127	122
65	157½	133	137½	102
70	168	140	148	102
75	178½	174	158½	146
80	190	170	170	130

Table II.

Temperature.	Loss after first minute.		Loss after fifth minute.	
	Zinc to coil.	Copper to coil.	Zinc to coil.	Copper to coil.
50°	59	59	45	45
55	86	86	69	69
60	116	116	98	98
65	154	154	135	135
70	218	218	195	195
75	315	315	200	200
80	445	445	425	405
83	550	535	520	495

Table III.

Temperature.	Loss after first minute.		Loss after fifth minute.	
	Zinc to coil.	Copper to coil.	Zinc to coil.	Copper to coil.
60°	153	150	102	112
65	182	190	113	125
70	225	245	130	147
75	290	320	185	180

On the Retardation of Signals through long Submarine Cables. *By* Fleeming Jenkin.

This paper contains the result of experiments made on long submarine cables, at the establishment of Messrs R. S. Newall and Co.

Professor Thomson's theory* is confirmed by these experiments, which indeed were only rendered possible by the use of Professor Thomson's Patent Marine Galvanometer.

The deflections of the magnet in this galvanometer are read by means of a spot of light, reflected by a mirror attached to the magnet, and brought to a focus on a scale at about 22 inches from the mirror. The magnet and mirror together weigh only $1\frac{1}{2}$ grain, and a very small angular movement of the magnet causes the spot of light to move over many degrees of the scale.

By this instrument a gradually and rapidly increasing or decreasing current is at each instant indicated at its true strength.

When therefore this galvanometer is placed as a receiving instrument at the end of a long submarine cable, the following phenomena are seen. At the moment of completing the circuit through battery, cable, and earth at the sending end, no movement of the spot of light occurs. In a second or less the spot begins to traverse the scale, at first slowly, then rapidly, and again more slowly, until after perhaps a minute a maximum is attained.

The interval of time which elapses between the first completion of the circuit and the arrival of the spot of light at various divisions of the scale was measured, and the observations being thrown into a curve, have given what may be termed the "curve of arrival" for various lengths.

Instead of one continuous current, broken currents, such as form dots and dashes in the Morse alphabet, were also sent with regularity by means of a metronome, and the movements of the spot of light corresponding to the various signals observed and delineated by curves.

The following are the results of the observations:—

1. The strength of the battery used does not affect the speed of transmission; to prove this, the curve of arrival was taken with 72 cells on a length of 2168 knots and with 36 cells. The two curves coincided when drawn to scales proportionate to the electromotive force of the two batteries. Thus is once more proved the fact that the speed of electricity is independent of the power of the battery, the current always reaching the same fraction of its maximum strength in the same time.

2. The same curve represents the gradual increase of intensity in a current when arriving, and the gradual decrease of intensity caused by putting the sending end of the cable to earth.

3. The curves of arrival, as obtained from lengths of 1000 to 2000 knots, agree in general character with those given by Professor Thomson's formula. Some discrepancies appear, due probably to electro-magnetic induction between the coils, and also in great measure to the varying resistance of the insulating cover, described in the author's paper "On Gutta Percha as an Insulator."

4. Whatever length of the cable was used for experiment, the amplitudes of oscillation representing dashes, or A's or other letters, were found to bear a constant proportion to the amplitudes representing simple dots sent at the same speed. This proportion is, however, different for each amplitude. Thus on a length of 2191 knots the speed of 15 dots per minute reproduced the same amplitude of oscillation as a speed of 30 dots on a length of 1500 knots; and the same relative speeds reproduced the same oscillations for dashes, A's, &c. in the two lengths. The amplitude is in this paper supposed always to be measured as a fraction of the maximum deflection obtained by keeping the circuit completed till the spot of light comes to rest.

5. The speed at which signals could be received on a relay, is easily perceived when the groups of oscillations are graphically delineated. A certain constant amplitude of dot corresponds to this speed (*vide* § 4). The speed at which a given amplitude of dot can be produced, varies inversely as the square of the length; and therefore the speed at which signals can be received by a relay varies also inversely as the square of the length of the cable.

* Proceedings of the Royal Society, May 1855, republished in the Philosophical Magazine.

6. By the usual hand-signalling, it was found just possible that legible groups of dots and dashes should be received through 1800 knots at a speed of 20 dots per minute.

7. The amplitude of oscillation due to various relative speeds can be thrown into a curve which is the same for all lengths; and since the law of retardation does not depend on the nature or dimensions of the material forming the cable, we can by means of this curve determine from one single observation at any speed, the amplitude of oscillation which will be due to any other speed, or in other words, the possible speed of signalling.

8. The maximum speed of signalling by any given system corresponds, as has been observed, to a certain amplitude of oscillation produced by successive dots. The actual amplitude necessary for each system must be determined by experiment.

For Morse-signals sent by hand, it can hardly be less than 15 to 20 per cent. of the maximum strength of current due to the battery used.

Mechanical senders would greatly increase the speed at which signals can be transmitted.

9. A comparison was made between signals sent by alternate reverse currents and those sent by alternate contacts with one pole of the battery and earth. One diagram would serve for both sets of signals, by simply drawing a line parallel to the base-line of the curve at half the height of the maximum, this line being taken as the base- or zero-line for the signals sent by reverse currents, all deflections above this line being called positive, all those below negative.

10. The use of reverse currents is of advantage in the first signals sent after the line has been completely discharged; the nature of this advantage may be briefly indicated by pointing out that, when no signals are being sent, the spot of light rests on the base-line, which in the common system is at a remote part of the scale from that at which the dots and dashes appear, but in the system of reversals is in the very centre of that portion of the scale.

The conclusions and experiments were, in the original paper, illustrated by diagrams.

On some of the Methods adopted for ascertaining the Locality and Nature of Defects in Telegraphic Conductors. By Cromwell F. Varley, *Electrician of the Electric and International Telegraph Company, and of the Atlantic Telegraph Company, &c.*

The author said the plans adopted by him were various: viz.—

Case 1.—When a conductor "makes dead earth," *i. e.* the *connexion* between the conductor and the earth offers no appreciable resistance, the operation is very simple, and consists solely in ascertaining how much resistance the conductor in question offers to the passage of electric currents.

Modes of Measuring Resistance.

He preferred using a standard of resistance and a differential galvanometer. A current from a battery, whose positive pole is connected to the earth, is made to divide and pass round the differential galvanometer in opposite directions. The one half of the current is made to enter the cable whose resistance is to be measured, and the other half to go through the resistance coils to the earth. So much resistance is then included in the latter circuit as shall make the divided currents equal in force, when the needle will stand at zero. The number of resistance coils required to make the needle stand at zero indicates the resistance of the conductor; and if the defect in the insulation be so large as to offer no appreciable resistance at the fault, the amount of resistance will indicate the locality of the fault.

When no resistance coils are at hand, the following method may be adopted:—

1st. Having a galvanometer whose resistance is known, and a Daniel's battery, first ascertain that each cell is in good order, and offers no appreciable resistance compared with that of the galvanometer.

2nd. Connect one pole of the battery to the earth, and the other through the galvanometer to the cable.

3rd. Note the deflection.

4th. See how many cells will give the same deflection when only the galvanometer is in circuit.

5th. Repeat 2nd, 3rd, and 4th with various powers, and take the mean of many results.

The following formula will then give the resistance of the conductor:—

Resistance of galvanometer	r.
Number of cells required in operation No. 3	n.
Number of cells when galvanometer only is in circuit	n'.
Resistance of cable.	x.

Then

$$\frac{r+x}{n}=\frac{r}{n'}, \text{ and } x=\frac{nr}{n'}-r.$$

With moderate care this will indicate the resistance to within 2 or 3 per cent. Care must be taken that the earth-plate used, and also the battery-cells, offer no appreciable resistance.

Resistance coils and a differential galvanometer are much more exact, and should always be used if possible. The author's standard, which has been adopted by the Electric and International Telegraph Company, the Atlantic and other Telegraph Companies, consists of the following units: 1, 2, 3, 5, 10, 20, 30, 50, 100, 200. These allow of the coils being checked by themselves; thus $1+2=3$, $2+3=5$, $2+3+5=10$, &c., which is very useful in practice.

Powerful currents must not be allowed to flow long through the coils, because they are thereby warmed and their resistance increased.

Case 2.—When (as is almost always the case) the fault itself offers resistance, but the conductor is otherwise perfect, one of the two following methods will indicate with sufficient precision the amount of resistance due to the conductor between the operator and the fault, and also that of the fault, the former being the distance of the defect:—

1st. Have the conductor disconnected at the distant end (B), and measure the resistance . . . . $=$R

This is the resistance of the conductor between the operator's end (at A) and the fault, plus that of the fault $(x+z)$.

2nd. Have the conductor "put to earth" at B, when the current on arriving at the fault, will split. Measure the resistance now $\left(x+\frac{yz}{y+z}\right)$ . . . . $=r$

3rd. The resistance of the conductor alone when perfect . . . . $=$S

Calling x the distance or resistance of the cable between the operator and the fault,

,, y the resistance of the cable between the fault and B, and

,, z the resistance of the fault itself,

we have

$$x+z=\text{R}$$

$$x+y=\text{S}$$

$$x+\frac{yz}{y+z}=r,$$

whence $x=r-\sqrt{r^2+\text{RS}-\text{R}r-\text{S}r}.$

In practice substitute for $\text{R}-r=\text{D}$,

and for $\text{S}-r=\text{D}$,

and then $x=r-\sqrt{\text{D}d}.$

This operation should, if possible, be repeated at the end B, which will indicate the possible amount of error.

Plan No. 2 requires that there be at each end galvanometers of known resistance, and which give actual measure (sine or tangent galvanometers giving absolute measure).

1st. Let A put on a current through his galvanometer to the cable, and let B connect the cable through his galvanometer to the earth.
2nd. Note the current e entering at A . . . . $=e$
and the current e' received at B . . . . $=e'$
3rd. Put on a battery at B and take away that from A, and now note the current f entering at B . . . . $=f$
and that received at A$=f'$ . . . . $=f'$
4th. Call the resistance of the conductor from A to the fault . . $=x$
5th. From the fault to the end of the cable . . . . $=y$
6th. Call the difference between $e-e'$ . . . . $=\mathrm{D}$
7th. Call the difference between $f-f'$ . . . . $=d$
8th. Call the resistance of A's galvanometer. . . . . $=\mathrm{G}$
9th. Call the resistance of B's galvanometer. . . . . $=g$

and then

$$\frac{x+\mathrm{G}}{y+g}=\frac{de'}{\mathrm{D}f'}.$$

In both of these cases, when the resistance of the fault is considerable, it is often difficult to obtain accurate results, as the fault's resistance varies considerably at times, especially if the current used be positive (+).

But when there are two or more wires between the stations in question, the following method removes all difficulty, and gives very accurate results.

Case 3.—At the distant station B have the defective wire connected to a good one, forming a loop from A to B and back again to A. Connect now the positive pole of a battery to the earth, and the negative pole to the differential galvanometer. Connect the one wire of the differential galvanometer to the good conductor, and the other wire through the resistance coils (rheostat) to the defective wire. The current from the battery will now split one portion of the current going through the good wire to the fault, the other portion going through the resistance coils to the faulty cable, and then to the fault where current escapes to the earth. Introduce now so much resistance as shall make the two channels equal. Call this resistance R, and then

$$x+y=\mathrm{S}, \quad \ldots \ldots \quad (1)$$

$$x+\mathrm{R}=y+\mathrm{S}, \quad \ldots \ldots \quad (2)$$

whence

$$x=\mathrm{S}-\frac{\mathrm{R}}{2}.$$

In this way a defect in one of the wires in the Mismeer and Zandvoort cable was tested, for the fault was $54\frac{1}{3}$ knots from the English coast; and when the fault was cut out, the error was less than the one-third of a mile. The cable being 115 nautical miles in length, the error was less than 0·3 per cent.

The author mentioned a case where the conductor was 120 miles in length, and the defect offered a resistance of from 1000 to 2000 miles, varying continually in amount. Plans Nos. 1 and 2 were tried, as also several others, but the results were very uncertain, and would not indicate the locality nearer than within 30 miles of the true position. This led him to invent plan No. 3, which left a possible error of only 2 or 3 miles. In this case the leakage due to all gutta percha, and which is very small, would have produced an error of 4 miles had it not been allowed for. Thus far conductors which are continuous, but whose insulation is defective, have alone been spoken of.

When the cable or conductor is broken asunder, one of the following plans will indicate approximately the amount of resistance due to the fault itself.

Case 4.—A cable broken asunder, if possible measure the resistance from each end; and if the exposed end of the broken cable offer only a very little or no appreciable resistance, the two amounts added together will be equal to that of one perfect wire; *i. e.* calling x one portion of the broken cable, and z the resistance of its exposed end, and y the other portion of the cable, and z' its ends' resistance, then if $x+z+y+z'=S$, the resistance of a perfect wire, it is evident that $z+z'$ offer little or no appreciable resistance, and the locality of the fault is immediately known. When, however, z or z' offer resistance, the value of z may be approximated either by measuring the amount of electrostatic charge of the cable, or by measuring the resistance, first with negative and then with positive currents.

It sometimes happens that one of the exposed ends of the conductor gets entangled with the iron outer wires of the cable. This is to be sought for; and if such be the case, it offers no appreciable resistance: this is immediately ascertained by connecting the conductor of the cable through a delicate galvanometer to the iron outer covering, when, if the copper wire at the fault be not in contact with the iron wires, an electric current will be found to flow through the galvanometer. The electromotive force of this current should be tested, and it will generally be found equal to an iron copper pair charged with sea-water. If the conductor touch the outer iron, there is no current through the galvanometer. If there be the current,—

1st. Measure the resistance of $x+z$ with negative current, and note whether it varies in amount.

2nd. Measure the resistance as before, but with a positive current, and note how it varies. If it vary much, especially with the negative current, it indicates that the fault offers much resistance.

3rd. Make an artificial fault, or rather several faults, that behave like the cable, with a like resistance to that of the cable, and with the same battery power. Having made such a fault that resembles as nearly as possible the cable with positive and with negative currents of *various powers*, measure its resistance, and subtract that amount from $x+z$, and that will indicate the distance of the fault. The positive current decomposes the sea-water and its salts, oxygen and chlorine are set free and combine with the copper wire at the fault, forming a coating offering considerable resistance to the passage of the current. In this way the resistance of a fault may often be very considerably increased. If it can, it shows that the surface exposed at the defect is small, and offers considerable resistance even with a negative current. A negative current covers the exposed wire with hydrogen, which keeps it clean and in good contact with the water, unless the aperture admitting the water be very small, and located in shallow water, when the hydrogen will sometimes expel the water and so increase the resistance.

The next plan of ascertaining the resistance of the fault, is by measuring the induction or statical charge and discharge. The author detailed several plans of doing this approximately, and indicated how an apparatus might be made to effect this perfectly, and which he had tried on a small scale with perfect success. He then showed how he had tested for the faults in the Atlantic Telegraph Cable, and pointed out the utter impossibility of the great fault being in the Valencia harbour, and which was proved by two distinct modes of testing. The exposed copper wire at the fault, formed with the iron outer covering a voltaic element of copper and iron. He contrived with this battery alone to measure the resistance of the cable and the fault. Much depends on the skill of the manipulator in choosing those plans most suited for the occasion.

After detailing several curious defects, he showed that when the defect in a cable was small and immersed in clay-mud, the fault might often be sealed up by a positive current so completely as to enable the conductor to be used. In this way he had sealed up one of the Orfordness Scheveningen Cable, which was defective, and thus kept it working above eighteen months; and when it got bad, it was again and again sealed up by strong positive currents. He stated that he had used some of the plans described for the last twelve years, and had rarely, if ever, found a greater error in the estimated distance than 5 per cent. of the cable tested. The plans detailed, as far as the author was concerned, were original, save No. 2, which was partly borrowed from the Abbé Moigno's treatise on Electric Telegraphs.

CHEMISTRY.

On the Action of concentrated Sulphuric Acid on Cubebin in relation to the test for Strychnine by Bichromate of Potash and Sulphuric Acid. By JAMES S. BRAZIER, *F.C.S., Fordyce Lecturer in Marischal College, Aberdeen.*

In the 'Chemical Gazette,' vol. xiv. page 251, there is an account by M. E. Boli, Professor of Chemistry and Mineralogy at the Academy of Medicine in Lima, of the behaviour of several organic substances towards bichromate of potash and sulphuric acid. All the substances enumerated by him appear to have a well-marked distinction by means of this test to that of strychnine, most giving a colour of some shade of green; some few, no reaction whatever. Casually repeating a similar series of experiments as a class illustration, with such alkaloids as I had in my possession, using at once $KO, 2CrSO_3$ and $HOSO_3$, I found that cubebin gave a reaction very different to many, and approached to some extent the reaction of strychnine, the colour produced being deep rose-red, which is perhaps more likely to be confused with the colour produced by strychnine, when the reaction has been standing for a short time, or if the alkaloid is in small quantity, or if the dish in which the experiment has been performed is not absolutely cold. I found, however, that by allowing the cubebin reaction to remain for some considerable time, the red colour gradually changed to a dingy green.

On repeating the experiment in other ways, I found that the sulphuric acid alone was sufficient to produce this red colour with cubebine, and as strychnine produces no colour with sulphuric acid alone, this serves as an easy test between the two.

The reaction above alluded to was quite new to me; nor could I find it noticed in any Journal; so that I thought it worthy of a comment on the present occasion.

On Distilled Water. By JAMES S. BRAZIER, *F.C.S., Fordyce Lecturer in Marischal College, Aberdeen.*

Notice of Dugong Oil. By JAMES S. BRAZIER, *F.C.S., Fordyce Lecturer in Marischal College, Aberdeen.*

The author presented notices of a remedy, obtainable in Moreton Bay, possessing valuable properties for the renovation and restoration of the human frame when worn out and exhausted by chronic disease. The discovery of such an agent within our own territory has long been considered a desideratum by the profession; and it appears to be a remarkable as well as felicitous arrangement of nature, that, in a locality possessing probably one of the finest climates in the world—combining both the soft humid atmosphere of Torquay and Madeira in the summer, with the dry bracing air of Nice and Pau in the winter, the resort, too, of valetudinarians from all parts of the world—a remedy should be found so potent in the treatment of chronic disorders.

About fourteen or fifteen years ago Baron Liebig's work on Animal Chemistry was first published, explaining the chemical process of respiration and nutrition, suggesting the method which ought to be adopted, and the principles which ought to guide us in the investigation of that important subject. Liebig, in that masterly work, compared the animal body to an apparatus of combustion, a furnace which we supplied with fuel, and showed that this combustion was supported by the oxygen of the atmosphere taken into the lungs in the act of respiration, meeting with the carbon taken into the system in the process of nutrition. Two or three years after the appearance of this work, a highly carbonized substance called cod-liver oil became a popular remedy in the treatment of consumption, to feed probably the flame of "the expiring lamp," as Kirke White in his 'Sonnet to Consumption' so beautifully yet significantly expresses it; and since that period its use has been progressively increasing, until at length its administration has become universal in almost every form of chronic disease.

At first it was thought that the infinitesimal proportion of iodine which cod-liver oil contained was its active element; but that theory being now exploded, its powers are generally attributed to the 80 or 90 per cent. of carbon it contains. This oil is procured from the livers of cod fish, and its taste is as disagreeable as its train-oil-like odour. So unpleasant indeed is this oil, that there are very few persons who can take more than three or four tablespoonfuls in a day, which at the most will only yield 2 ozs. of carbon to the system, towards 13·9–10 oz. required, leaving a fearful balance against the sick man. Fortunately, however, the theory is better than the remedy commonly used, and the sick people of Australia are singularly favoured in having in their own territory an herbivorous cetaceous animal, the Dugong (*Halicore Australis*), inhabiting the rivers and bays of the eastern coast, from Moreton Bay to Cape York, from which an oil can be procured possessing all the properties required for this purpose.

So sweet and palatable is the oil procured from the Dugong, that in its *pure state it may be taken* without disagreeing with the most sensitive stomach, and also used in a variety of ways in the process of cooking; so that this potent restorative remedy may be taken as food, and many ounces consumed almost imperceptibly every day, and thus furnish the system with the requisite amount of carbon for its daily oxidation.

Believing Elaiopathy, or oil administration, to be a rational mode of treatment, and dissatisfied with the nauseous train-oil-like fuel usually supplied to our sickly furnaces, the author made diligent search for a substitute, and now unhesitatingly communicates, after testing the powers of the discovery for nearly five years in a great variety of chronic disorders, that the Dugong oil is one of the most potent and reliable remedies he has ever met with in the treatment of chronic disease.

Laboratory Memoranda. By J. S. Brazier, *F.C.S., Fordyce Lecturer in Marischal College, Aberdeen.*

On the quantitative estimation of the soluble combustible contents of a water.

This item of an ordinary analysis of a water, which commonly passes under the general description of "organic matter," is frequently obtained as follows:—by evaporating a portion of the water to dryness, to weigh the residue, and afterwards to heat it to low redness till it ceases to lose weight, when the difference from its former weight would be considered the "organic matter."

In burning off the combustible portion of the total dry evaporated contents, two chief sources of error may be observed:—first, carbonic acid is apt to be expelled from the incombustible mineral contents by the action of the combustible matter under a high temperature, the residue giving an alkaline reaction to test paper; second, when a very high temperature is applied in order to burn off the combustible portion, some of the incombustible mineral portion is volatilized, and thus comes to be erroneously reckoned as part of the combustible soluble contents. In consequence of these observations, the following method of procedure is adopted by the author.

The evaporating basin is of platinum, about 600 grains in weight, and about a quarter of a pint in capacity. The measure of water evaporated in each trial is one-fifth of a gallon (=14,000 grains). To prevent any minute increase of weight from fused adhesions to the outside of the basin during long exposure to flame, heat is applied by means of a water-bath. The evaporated mass is dried in a Taylor's hot-air bath at a temperature of 230° Fahr., and is then weighed. The nett weight gives the total soluble contents, both combustible and incombustible. A temperature of 260°, as often as it was tried, gave no differance in the weight.

The scorching is produced by heating the outside of the evaporating basin by the flame of a spirit-lamp, kept as weak as can burn off the combustible matter. The evaporated mass, after being scorched, is moistened with a solution of pure carbonic acid in distilled water, is dried anew in a Taylor's air-bath at 230° Fahr., and is weighed a second time. The nett weight gives the incombustible (or mineral) soluble contents alone, which on being subtracted from the former nett weight of both combustible and incombustible, left the combustible alone.

The heat of the spirit-lamp is preferable on account of the variation which is so frequently caused in platinum vessels by heating them over a gas-flame; apparently some carbon compound is produced, and, in proportion to the more or less perfect combustion of the gas flame, the platinum dish becomes lighter or heavier, thus causing an error in the weight of the contents of the dish.

An increase in the measure of water evaporated fails to increase the accuracy of the results; for an increased quantity of mineral matter makes the thorough combustion of the evaporated mass more difficult, and so necessitates the application of a very high temperature, which produces error, by volatilizing a portion of the mineral matter.

This is not an exact method of estimating combustible or organic matter, there being none; still it is as correct as any known, and affords uniform results, which the ordinary process assuredly does not.

Mr. C. J. Burnett exhibited some specimens illustrating the use of Platinum in Photography.

On the Ageing of Mordants in Calico Printing. *By* Walter Crum, *F.R.S.*

The process of "ageing" in calico printing is that by which a mordant after being applied to a cotton fabric, is placed in circumstances favourable to its being incorporated with and fixed in the fibre; and the method usually employed has been to suspend mordanted goods in an apartment in single folds, exposed to the atmosphere.

The object is to moisten the acetates of iron and of alumina in order to their decomposition; and in ordinary circumstances a pound of water is gradually absorbed by fifteen pounds of printed cloth. The protoacetate of iron is thus enabled, by imbibing oxygen, to become a sesquiacetate like the bisalt of alumina. Each then proceeds to give off acetic acid, and to deposit a tersesquihydrate upon the fibre.

Various methods have been employed in this country for adding to the natura. moisture of the air, but with no great advantage, until Mr. Jones introduced into Messrs Schwabe's works near Manchester a system of ageing which he had seen in operation at Mulhausen, and succeeded, by the direct introduction of steam underneath, greatly to increase the heat and moisture of the large apartment in which his mordanted goods were hung, and thus to render the process of ageing not only more speedy, but much more perfect than before. But the employment of steam was in that case limited in amount, chiefly by the discomfort to which it subjected the work people in the apartment, and by the damage produced by drops of water falling from their persons upon the goods.

In the summer of 1856, Mr. Jones visited Thornliebank, and described that method of ageing. It became then not difficult to conceive that, by a further increase of heat and moisture in an apartment sufficiently capacious, and by employing a great number of rollers, goods might become sufficiently moistened without manual labour by being merely passed through such an atmosphere; and that thus, the pieces being stitched end to end, a continuous process might be substituted for that of hanging goods over wooden rails, and leaving them there until the ageing is completed.

The idea of passing printed goods through an atmosphere artificially moistened was not new. It had even been patented by Mr. John Thom of Manchester; but the apparatus of that gentleman was too small to be practically useful. The present improvement consists in rendering the process a practicable one; and the various adaptations introduced for that purpose will appear in its description.

A building is employed 48 feet long inside and 40 feet high, with a midwall from bottom to top running lengthwise, so as to form two divisions each 11 feet wide.

In one of these divisions the goods first receive the moisture they require. Besides the ground floor, it has two open sparred floors 26 feet apart, upon each of which is fixed a row of tin rollers, all long enough to contain two pieces of cloth at their breadth. The rollers, being threaded, are set in motion by a small steam-engine, and the goods to be aged, which are at first placed in the ground floor, are drawn into the chamber above, where they are made to pass over and under each roller, issuing at last at the opposite end and folded into bundles on one (at a time) of three stages which are placed there. These stages are partially separated from the rest of the chamber by a woollen partition.

While the goods are traversing these rollers, they are exposed to heat and moisture, furnished to them by steam, which is made to issue gently from three rows of trumpet-mouthed openings. The temperature is raised to from 80 to 100° or more of

Fahrenheit,—a wet-bulb thermometer indicating at the same time 76° to 96°, or always 4° less than the dry-bulb thermometer. In this arrangement 50 pieces of 25 yards are exposed at one time, and as each piece is a quarter of an hour under the influence of the steam, 200 pieces pass through in an hour.

The mordant, having thus received the requisite quantity of moisture, must be left one or two days in an atmosphere still warm and moist; and in some cases it is advantageous to pass the goods a second time through the rollers.

It had fortunately been ascertained long before, at Thornliebank, that exposure in single folds after moistening was not necessary. Mr. Graham's experiments on the diffusion of gases through small apertures had served to suggest that, for the absorption of the small quantity of oxygen required, the goods might as well be wrapped up and laid in loose heaps. Accordingly, in the operation in question, the moistened goods are carried in bundles into the building on the opposite side of the midwall already mentioned, and deposited upon the sparred floors, which are placed there at heights corresponding with the stages in the first apartment, on which the goods are folded down. Upon these floors five or six thousand pieces, of twenty-five yards long, can be stored at a time. It is necessary, of course, that an elevated temperature, and a corresponding degree of moisture, be preserved in the storing apartments day and night; and 80° Fahr. is sufficient, with the wet bulb at 76°.

The process of ageing, as thus detailed, was in operation at Thornliebank in the autumn of 1856. About a year afterwards it began to be adopted by other printers, and now (in September 1859) it is already in use at least sixteen different printing establishments in Scotland and in Lancashire.

On the Molecular Movements of Fluids.
By THOMAS GRAHAM, *M.A., D.C.L., Master of the Mint, F.R.S.*

On a Symmetrical Arrangement of Oxides and Salts on a Common Type.
By DR. LYON PLAYFAIR.

Salts, according to the present views, may be constituted of an oxide and an acid; of an electro-positive element and an electro-negative salt radical; or on the type of water in which the hydrogen is sometimes replaced by an electro-positive element, sometimes by an electro-negative compound. The author adopted the whole series of metallic oxides as typical of salts, supposing that two equivalents of the metal were present in all the oxides except the magnetic oxide. He contended that neutral salts are not formed on the type of a basic oxide, such as water, but on that of a neutral oxide, such as peroxide of manganese or peroxide of hydrogen, of the general formula $O_2(MM)O_2$. Two equivalents of the oxygen in this type may be replaced in a neutral salt by an anhydrous acid, so that the general formula of a neutral salt is either $O_2(MM)A_2$, or half that value, in which A represents any acid. The author showed that many facts supported the idea that an anhydrous acid could substitute oxygen directly, and *vice versâ*. Thus, carbonate of manganese heated in air becomes peroxide, oxygen substituting the acid; while peroxide of copper loses oxygen in air and becomes a carbonate. Barytes heated in air absorbs oxygen and becomes a peroxide; heated with sulphuric acid, it becomes a sulphate; both oxide and salt being formed on the same type. The author then proceeded to show that as there are varieties of oxides, so also there are varieties of salts, each constituted on an oxide type. Salts of suboxides represent the protoxides; subsalts, with two equivalents of an oxide and one of an acid, are formed on the type of sesquioxides; while those with three of a base and one of an acid, like phosphate of soda, are formed on the type of magnetic oxide of iron. The sesquisalts, on this view, are on the type of manganic acid, $O_3(MM)A_3$, being like $O_3(MM)O_3$. The author then proceeded to show how various relations became apparent, if the oxygen in the oxides were arranged in the simplest form, of an axis and equator around the metallic nucleus, according to a conventional system, on a plane surface. The existence or deficiency of symmetry in the structure of a body becomes thus indicated. As a general conclusion, when there is an equal balance in the molecules of oxygen, or of electro-negative bodies playing its part, then rest or neutrality results; when the structure wants balance or symmetry, then activity is manifested—basicity when the electro-positive molecules predominate; acidity when the electro-negative are in excess. By writing *minus* points to show the want of symmetry, it is possible to indicate *à priori* whether an acid is monobasic, bibasic, or tribasic. In conclusion, the author referred to the oxides of nitrogen, chlorine, and carbon as illustrations of the importance of symmetry. Writing them all on four-volume formulæ, it is necessary to double them when the compound has an uneven number of molecules of oxygen; but the oxides of an even number do not require this duplication. Further, it was shown that the symmetrical oxides are neutral or only feebly acid in character in the case of the oxides of electro-negative elements. Thus hypochlorous, chlorous and chloric acids are uneven, like nitrous and nitric acids; while binoxide of nitrogen and the peroxides of chlorine and nitrogen are neutral from there being a balance in the molecules of oxygen. In like manner oxalic acid, with an uneven number of atoms of oxygen, is more powerfully acid than carbonic acid, where the conditions for symmetry are more nearly satisfied.

On two new Photochemical Experiments. By M. Niepce de St. Victor.

1*st Experiment.—Chemical Photometer.* Into a flask with a neck is introduced a solution of oxalic acid so concentrated that a portion of the salt remains undissolved at the bottom; into this solution a certain quantity of a solution of nitrate of uranium, or simply of oxide of uranium, is next poured; the flask is then hermetically sealed by a cork, through which passes a straight, graduated tube, whose lower extremity reaches below the surface of the lquid, and whose upper one rises to a certain height above the cork. The apparatus being thus constructed, no particular phenomenon manifests itself so long as the bottle remains in the dark; the liquid in the tube remains at the same level as that in the flask: but when exposed to diffuse, or to direct solar light, the oxalic acid, under the influence of light aided by the presence of a salt of uranium, becomes decomposed and gives rise to the formation of carbonic oxide, which latter, collecting in the flask and pressing on the surface of the liquid, causes the same to rise in the tube with a rapidity and to a height proportional to the chemical intensity of the light. The little apparatus is in fact a chemical photometer, and acts admirably; it remains to be seen whether the proportionality between disengagement of gas and chemical intensity is constant, and whether by this means it would be possible to measure accurately the chemical action of diffuse or solar light at different elevations of the sun, at various seasons and at different places; whether, in short, the mixture of M. Nièpce de St. Victor is capable of completely replacing the gaseous sensitive mixture of Bunsen and Roscoe. We earnestly recommend this new kind of experiment to M. Poey, who resides in the favourable climate of Havanna. The magnitude of the tube's diameter and the best method of graduation also remain to be determined.

2*nd Experiment.—Photochemical Pile.* In this experiment a flask is chosen with a wide neck through which two plates may be passed, one of zinc and the other of copper; to these plates two copper wires are fixed so as to form a small element of a simple pile. The liquid, or rather the mixture of liquids poured into the flask, is the same as in the preceding apparatus, viz. a solution of oxalic acid with an excess of salt and a solution of oxide or of nitrate of uranium. When the circuit is closed, even in the dark, an action at once commences, and a current is produced capable of deflecting the needle of a sensitive galvanometer. But when the flask is exposed to the light the action becomes incomparably more energetic, the quantity of carbonic oxide formed is very considerable, its disengagement in the form of smoke or transparent cloud is visible to the eye. To a certain degree the oxide or nitrate of uranium may be replaced by nitrate or perchloride of iron.

Geology.

On the Discovery of Silurian Fossils in the Slates of Downshire. By James Bryce, *M.A., LL.D., F.G.S.*

In a paper laid before the Geological Section of the Association at the Belfast Meeting in 1852, the author has described the structure of these slates and their interesting relations to the Sliabh Croob and Morne granites, by which they are invaded. He had noticed also the existence of anthracitic beds in them, but was unable to produce any well-marked fossils in proof of the Silurian age of the beds. That they were of this age, however, there seemed no reasonable doubt, from the fact long ago established by Buckland and Conybeare, that they are in direct continuation of the great slate-bands of the South of Scotland, in which Silurian fossils have been of late years abundantly found. Since the period referred to, a more active examination of the rocks has been set on foot. At the request of the author and his friend Mr. James M'Adam, F.G.S., of Belfast, the well-known collector Mr. Patrick Doran had examined certain favourable localities, and, with his usual success, had brought to light several well-preserved fossils, the greater number of which seem to be Upper Silurian forms. There are several Trilobites and Graptolites, two Mytili, a Sanguinolaria, an Orthoceras, and the *Loxonema obscura*, a characteristic Upper Silurian fossil. The author described a section reaching from the triassic beds of Belfast Bay through the Carboniferous and Permian formations, brought into contact near Holywood by a fault, and across the Silurian tracts of the middle of the country to the two granitic protrusions already mentioned. On this section, between Comber and Ballynahinch, in the townland of Tullygirvan, the fossils were discovered. A more detailed account was promised at an early period.

On the newly discovered Reptilian Remains from the neighbourhood of Elgin. By THOMAS H. HUXLEY, *F.R.S., Professor of Natural History, Government School of Mines.*

The author described the principal features of the large series of Reptilian remains from Elgin, which had been placed in his hands for examination, and the greater part of which were exhibited to the Section. They consisted of portions of the skull with teeth, of cervical, dorsal, sacral and caudal vertebræ, and ribs, coracoid, scapula, and bones of the extremities, together with dermal scutes from various parts of the body, of *Stagonolepis Robertsoni*. The anatomical characters of all these remains were shown to be in entire agreement with that view of the true affinities of *Stagonolepis* which the author had been the first to propound, and demonstrated that it departed from the Crocodilian type even less than he had at first supposed.

An account was then given of the structure of the Lacertian, *Hyperodapedon Gordoni* from the same locality; and its resemblances to, and differences from, the Triassic *Rhynchosaurus* were discussed.

The foot-prints in the Elgin sandstones were also described, but their relation to either of the reptiles just mentioned was left an open question.

With respect to the geological age of these remarkable reptiles, the author expressed his conviction that, while their generic distinctness from any known *Reptilia* rendered it unsafe to make any very positive assertion upon the point, the affinities of *Stagonolepis* with the Liassic *Crocodilia*, and of *Hyperodapedon* with the Triassic *Rhynchosaurus* were so close, that nothing but the most conclusive stratigraphical evidence could justify the assumption of the Devonian age of the rocks in which they were found.

Numerous lithographic plates, forming a part of the illustrations of a forthcoming memoir upon these remains, were exhibited to the Section.

On the Section of the Coast between the Girdleness and Dunnottar Castle, Kincardineshire. By the Rev. Dr. LONGMUIR.

This communication was illustrated by a diagram of the different kinds of rocks occurring between these two points, and of the stratification in the harbour at the Cove, of the scenery at Muchalls, and of the junction of the Old Red Sandstone and conglomerate in the south side of the bay of Stonehaven. There was also a series of the different kinds and varieties of the rocks along the coast, which nearly extended along the whole side of the table. Beginning at the Girdleness, the Doctor stated that the Dee ran for several miles in the hollow formed between the granite and the gneiss, so that it was impossible to examine their union. A little to the south of the lighthouse, there occurs a reddish granite, enclosing masses of contorted gneiss, these showing that that granite at least was of more recent origin than the enclosed gneiss. Further on was an extensive section of the boulder clay, which exhibited many features in common with similar clays in other places; but there were no perceptible scratches on the boulders of gneiss and granite, as, to use the phraseology of their lamented friend, Mr. Hugh Miller, the Aberdeen granites were more likely to be the *scratchers* than the *scratchees*! He then showed specimens of the porphyry and hornblende rock, before coming to the Cove, where there is a seam of granite upwards of six feet in thickness, lying conformably to the hornblende schist. He then referred to the excellent and instructive section exhibited in the muckle shore of Findon, and aptly illustrated its structure by a book tilted upon one of its corners. He then described the highly picturesque views on the Muchalls shore, exhibiting specimens of the porphyries and strangely contorted gneiss, and had a stereoscope and the views of Mr. Wilson, which he invited parties to inspect at the close of the meeting. Next came the Garron, from which he exhibited rich iron ore, and showed that it was strongly magnetic. He then remarked that, near this point, where the Old Red Sandstone commences, there was a synclinal axis, and that the rocks, although towards Stonehaven they were nearly perpendicular, had a slight *northerly* dip. In exhibiting a specimen of the *whorl-rock* at the village of Cowie, he presumed that the name was derived from the whorls of the spindles made use of before the introduction of the spinning wheel—

When makin' *whorls* was a trade,
An' spindles in the time o' need.

But the most remarkable thing was that in this intercalated claystone he believed he had detected organic impressions; but this was yet under consideration. He then showed that green stone, *blue heathen,* occurred in a dyke on the south side of the bay of Stonehaven. Dr. Longmuir then proceeded to describe the various ingredients of the conglomerate, and remarked on the absence of fragments of granite except near the Castle of Dunnottar. He also described veins of pure carbonate of lime as traversing the conglomerate on which the ruins of the castle stand, and stated that there was a clearly defined fault in the sandstone of the Castle-haven.

On the Remains of the Cretaceous Formation, &c. in Aberdeenshire. By the Rev. Dr. Longmuir.

He stated that he had no intention of doing more than showing their friends from the south a series of specimens, which they might have little expected in a region of granite and gneiss. He was desirous of bringing forward a brief notice of those who had examined these fossils. That they were well known to their ancestors was evident from the flint arrowheads and axes which were occasionally turned up in cultivating the fields. A land-surveyor from Berwickshire, who had acquired a taste for geological pursuits from Dr. Hutton and Mr. Bruce, who afterwards became Secretary of the Natural History Society of Edinburgh, seems to have been the first to recognize their geological importance. His son brought these flints under the notice of Mr. C. Lyell, who determined that they were similar to those found in the English chalk. In 1834, Dr. Knight, formerly of this University, read a paper on the subject before the Association, of which only the title appears in the 'Transactions.' But in the course of twelve years, these chalk remains had nearly been forgotten, when he sent an account of his first examination of the Hill of Dudwick, in the neighbourhood of Ellon, to his lamented friend Mr. H. Miller, who was pleased to print it in the 'Witness.' Since that time he had visited the locality from Ellon to Peterhead, and brought the result of his examination before the Association in 1850, and now he wished to do little more than to submit the specimens to the examination of geologists. About twenty years ago, Mr. Johnston of Moreseat, in digging for a waterfall, got into a substance containing many singular impressions. An examination of these led him to infer that this was a portion of the green-sand, which the fossils as well as lithological character of the matrix fully confirmed. But he next proceeded to the lower ground nearer the sea, and found in hillocks of water-worn stones, several nodules of a yellow limestone, in which he had found both vegetable and animal remains, which were now on the table, and which papeared to him to be magnesian limestone. The origin of these fragments was either to be referred to the drift, or denudation. If drifted, the question *whence* naturally presented itself. It was true, in Denmark they had chalk *in situ*, but that was in the wrong direction. He would venture to suggest that, from the appearance of the ground and the position of the flints, these flints had been rolled on a beach which had afterwards been elevated.

On the Restoration of Pterichthys *in* '*The Testimony of the Rocks.*' *By the* Rev. Dr. Longmuir.

Dr. Longmuir stated that it was with emotions of the deepest sorrow that he ventured to do what, in all probability, would have been done by his friend Mr. Miller, had he been among them. The many-sided mind of that eminent man was such, that one beholder was struck with one aspect of it as the most extraordinary, another with a second, and another with yet a third. Thus one is astonished at his *memory*, that seemed to retain everything; another admires his powerful *imagination* and indomitable *perseverance*; but, from an intimacy of many years, as well as from the study of his works, he (Dr. L.) would advert to his *sagacity* as the most striking characteristic of his gifted mind. Hence he seemed intuitively to perceive what would have cost others no small amount of careful investigation. Those who were present at the meeting of the British Association in 1850, would remember his demonstration of what had previously appeared to him to be teeth in the ends of the jaws of the Coccosteus, although that opinion had originally been "written down a blunder on the very highest authority;" and so in his 'Testimony of the Rocks,' those who were familiar with his restoration of the *Pterichthys* in his 'Old Red Sandstone' must have been struck with the attachment of a triangular fin to the upper edge of the caudal extremity in his new representation of that remarkable fish, with which his name will be indissolubly connected. In one of the earliest specimens of *Pterichthys* which his "busy hammer" laid open, he thought he detected indications of this fin on the lengthy and angular tail; but, either deeming the evidence insufficient, or hoping one day to lay open a nodule that would less equivocally display the appendages of the tail, he did not venture to represent this caudal fin. This specimen he presented to his friend the Rev. John Swanson, who afterwards transmitted it, among several other fossils, to the Museum of King's College. As illustrative at once of his powerful memory and ardent perseverance, Mr. Miller, remembering the appearance and history of that specimen, came to Aberdeen on the last day of July, 1856, and consequently but a few months before his lamented death, to examine that specimen, and left a card upon it, on which he had pencilled, "*Pterichthys oblongus*, Cromarty (second specimen ever found);" together with a reference to his 'Schools and Schoolmasters,' for a notice of the specimen. Through the kindness of Lieut. Paterson, R.N., Cromarty, he (Dr. L.) was indebted for a beautiful specimen of the same fossil, in which the tail, bent along the side of the body, showed distinctly the small fins which Mr. Miller had restored along the edge of the tail, whilst other specimens from Lethenbar left no doubt as to the existence of the larger triangular fin, together with the spine on its upper edge by which it had been extended. (Dr. Longmuir illustrated his paper by diagrams of the former and later restorations of *Pterichthys*, and exhibited the interesting specimens to which he had referred.)

On Fossil Remains found at Urquhart, near Elgin. *By the* Rev. James Morrison. *Communicated by the* Rev. Dr. Longmuir.

These fossil shells, of well nigh 150 species, have all been found in a bank of clay having a frontage of a few yards and a depth of two: the clay, of a deep dark-blue colour, is regularly stratified. Some of the bands near the top have small stones and gravel mixed with them; some are arenaceous, and others purely aluminous. The shells are found in the lower beds, in irregular and rounded water-worn masses of no great size. These masses are of the same hue and material as the beds in which they lie, and are plainly unwasted fragments of the rocks from which the clay has been formed. The deposit can be traced for some two miles towards the sea, from which it is about four miles distant, though only a few feet above high-water mark. The fossils are almost exclusively molluscous. No teeth, scales, or bones of fishes or reptiles have been found. Univalves, with the exception of ammonites, sorely crushed in general, are rare and minute, corresponding in this respect to the neighbouring patch *in situ* of the Lias Marlstone near Shanbryde, where the rock is crowded with finely preserved bivalves with a stray univalve occurring now and then. Fragments of Belemnites, joints of Pentacrinites, and spines of Cidaris occur in goodly numbers. Bivalves are very numerous, in good preservation, and easily extracted. *Arca, Nucula, Leda, Lima, Mya, Perna, Ostrea, Gryphæa, Pecten, Gervillia, Placunopois, Anomia,* &c., are represented in large numbers and very considerable variety of form. Many of the larger shells are found lying in the clay as unworn as though they had died but yesterday. *Ostrea gigantea,* belonging to the Lias, and *Ostrea Marshii,* ranging from the Cornbrash to the Inferior Oolite, show that the deposit is not *in situ,* a conclusion to which the whole circumstances of the case would lead, apart from the palæontological evidence.

Similar remains are met with at many different spots of the long valley stretching from near the mouth of the Spey westwards to the Findhorn. In the Loch of Spynie, in Duffus, and Inverugie they have been found in great abundance and variety. The trough which lies between the Reptilian beds of Spynie and Findrassie on the south, and Lossiemouth and Covesea on the north, seems charged with these mingled remains of various divisions of the Lias and Oolite. The only point of importance regarding them is to determine whence they came; for plainly they are not *in situ.* Two hypotheses have been put forward. One is that they have been all transported by ice from some land far away. The extent of the ruins, the great regularity of the stratification, the identity of materials in the fossil-bearing masses and the clay which contains them, their position, in Urquhart at least, beneath the boulders of the drift, the presence in some of the beds of numerous fragments of the adjacent cornstones and sandstones, and the existence *in the clay* of unprotected Gryphæas unworn and uninjured,—all seem to point in a different direction.

The other hypothesis is, that we have here the re-arranged and re-formed debris of Oolitic and Liassic formations formerly existing in the neighbourhood, slowly wasted away by Old Ocean, and laid down again in new shape where they are now found. This appears the true explanation, and consists with and explains all the circumstances of the case. This view is confirmed by the fact that, at Linksfield and Shanbryde, we have large unbroken remnants of Lias in the latter place *in situ.* The recent discovery of an oolitic deposit *in situ* lying unconformably on the Lossiemouth sandstones, still further manifest the correctness of this second hypothesis. I regard then these fossils as furnishing evidence that the whole of the valley, from Findhorn to Spey, was at one period covered to a considerable depth with the Lias and Oolite. Formed in the depths of ocean, these had been elevated above its waters, and may have formed for uncounted ages the dry land of the Tertiary period. During the gradual depression of the morning of the glacial day, when the Scotland that now is was all but buried beneath the waters of an Arctic sea, the oolitic graveyard of Moray was brought within the reach of the wild waves, was slowly wasted and broken up; and its crushed and powdered materials, quietly deposited and reformed near the spot they originally occupied, were covered over by the sand and clay and boulders of the Drift. A counter movement then took place. The buried territory was slowly elevated. The rearranged oolitic debris rose to near the surface, where it remained until the upheaval to which we owe our raised beaches put it for a time beyond, but only just beyond, the destroyer's reach. But be the period and mode of operation what they may, there is enough to warrant the supposition that in these and kindred fossils scattered over the low ground, we have clear proof of the former existence of formations which have all but disappeared from among us. What bearing, if any, this may have upon the question of the age of our Reptilian sandstones, must be left for others to decide.

On the supposed Wealden and other Beds near Elgin. *By* C. Moore, *F.G.S.*

(See Abstracts of the Proceedings of the Geological Society, March 28, 1860.)

On Brachiopoda, and on the Development of the loop in Terebratula. By C. MOORE, *F.G.S.*

On some Observations on the Parallel Roads of Glenroy. By Professor H. D. ROGERS, *F.G.S.*

On Faults in Cumberland and Lancashire. By the Rev. Professor SEDGWICK, *M.A., F.R.S.*

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CONTENTS:—Rev. B. Powell, Report on the Present State of our Knowledge of Refractive Indices, for the Standard Rays of the Solar Spectrum in different media;—Report on the Application of the Sum assigned for Tide Calculations to Rev. W. Whewell, in a Letter from T. G. Bunt, Esq.;—H. L. Pattinson, on some Galvanic Experiments to determine the Existence or Non-Existence of Electrical Currents among Stratified Rocks, particularly those of the Mountain Limestone formation, constituting the Lead Measures of Alton Moor;—Sir D. Brewster, Reports respecting the two series of Hourly Meteorological Observations kept in Scotland;—Report on the subject of a series of Resolutions adopted by the British Association at their Meeting in August 1838, at Newcastle;—R. Owen, Report on British Fossil Reptiles;—E. Forbes, Report on the Distribution of Pulmoniferous Mollusca in the British Isles;—W. S. Harris, Third Report on the Progress of the Hourly Meteorological Register at Plymouth Dockyard.

Together with the Transactions of the Sections, Rev. W. Vernon Harcourt's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TENTH MEETING, at Glasgow, 1840, *Published at* 15s.

CONTENTS:—Rev. B. Powell, Report on the recent Progress of discovery relative to Radiant Heat, supplementary to a former Report on the same subject inserted in the first volume of the Reports of the British Association for the Advancement of Science;—J. D. Forbes, Supplementary Report on Meteorology;—W. S. Harris, Report on Prof. Whewell's Anemometer, now in operation at Plymouth;—Report on "The Motion and Sounds of the Heart," by the London Committee of the British Association, for 1839-40;—Prof. Schönbein, an Account of Researches in Electro-Chemistry;—R. Mallet, Second Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at various temperatures, upon Cast Iron, Wrought Iron and Steel;—R. W. Fox, Report on some Observations on Subterranean Temperature;—A. F. Osler, Report on the Observations recorded during the years 1837, 1838, 1839 and 1840, by the Self-registering Anemometer erected at the Philosophical Institution, Birmingham;—Sir D. Brewster, Report respecting the two Series of Hourly Meteorological Observations kept at Inverness and Kingussie, from Nov. 1st, 1838 to Nov. 1st, 1839;—W. Thompson, Report on the Fauna of Ireland: Div. *Vertebrata*;—C. J. B. Williams, M.D., Report of Experiments on the Physiology of the Lungs and Air-Tubes;—Rev. J. S. Henslow, Report of the Committee on the Preservation of Animal and Vegetable Substances.

Together with the Transactions of the Sections, Mr. Murchison and Major E. Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE ELEVENTH MEETING, at Plymouth, 1841, *Published at* 13s. 6d.

CONTENTS:—Rev. P. Kelland, on the Present state of our Theoretical and Experimental Knowledge of the Laws of Conduction of Heat;—G. L. Roupell, M. D., Report on Poisons;—T. G. Bunt, Report on Discussions of Bristol Tides, under the direction of the Rev. W. Whewell;—D. Ross, Report on the Discussions of Leith Tide Observations, under the direction of the Rev. W. Whewell;—W. S. Harris, upon the working of Whewell's Anemometer at Plymouth during the past year;—Report of a Committee appointed for the purpose of superintending the scientific co-operation of the British Association in the System of Simultaneous Observations in Terrestrial Magnetism and Meteorology;—Reports of Committees appointed to provide Meteorological Instruments for the use of M. Agassiz and Mr. M'Cord;—Report of a Committee to superintend the reduction of Meteorological Observations;—Report of a Committee for revising the Nomenclature of the Stars;—Report of a Committee for obtaining Instruments and Registers to record Shocks and Earthquakes in Scotland and Ireland;—Report of a Committee on the Preservation of Vegetative Powers in Seeds;—Dr. Hodgkin, on Inquiries into the Races of Man;—Report of the Committee appointed to report how far the Desiderata in our knowledge of the Condition of the Upper Strata of the Atmosphere may be supplied by means of Ascents in Balloons or otherwise, to ascertain the probable expense of such Experiments, and to draw up Directions for Observers in such circumstances;—R. Owen, Report on British Fossil Reptiles; Reports on the Determination of the Mean Value of Railway Constants;—D. Lardner, LL.D., Second and concluding Report on the Determination of the Mean Value of Railway Constants;—E. Woods, Report on Railway Constants;—Report of a Committee on the Construction of a Constant Indicator for Steam-Engines.

Together with the Transactions of the Sections, Prof. Whewell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWELFTH MEETING, at Manchester, 1842, *Published at* 10*s*. 6*d*.

Contents:—Report of the Committee appointed to conduct the co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—J. Richardson, M.D., Report on the present State of the Ichthyology of New Zealand;—W. S. Harris, Report on the Progress of Meteorological Observations at Plymouth;—Second Report of a Committee appointed to make Experiments on the Growth and Vitality of Seeds;—C. Vignoles, Report of the Committee on Railway Sections;—Report of the Committee for the Preservation of Animal and Vegetable Substances;—Lyon Playfair, M.D., Abstract of Prof. Liebig's Report on Organic Chemistry applied to Physiology and Pathology;—R. Owen, Report on the British Fossil Mammalia, Part I.;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—L. Agassiz, Report on the Fossil Fishes of the Devonian System or Old Red Sandstone;—W. Fairbairn, Appendix to a Report on the Strength and other Properties of Cast Iron obtained from the Hot and Cold Blast;—D. Milne, Report of the Committee for Registering Shocks of Earthquakes in Great Britain;—Report of a Committee on the construction of a Constant Indicator for Steam-Engines, and for the determination of the Velocity of the Piston of the Self acting Engine at different periods of the Stroke;—J. S. Russell, Report of a Committee on the Form of Ships;—Report of a Committee appointed "to consider of the Rules by which the Nomenclature of Zoology may be established on a uniform and permanent basis;"—Report of a Committee on the Vital Statistics of large Towns in Scotland;—Provisional Reports, and Notices of Progress in special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Lord Francis Egerton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTEENTH MEETING, at Cork, 1843, *Published at* 12*s*.

Contents:—Robert Mallet, Third Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and 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'Argile de Londres, with translation;—J. S. Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTEENTH MEETING, at Cambridge, 1845, *Published at* 12s.

CONTENTS:—Seventh Report of a Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lt.-Col. Sabine, on some points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843;—R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-Registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phænomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at* 15s.

CONTENTS:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical

Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—J. Percy, M.D., Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18s.

CONTENTS:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water:—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phænomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr. R. G. Latham, on the present state and recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Müller, on the Relation of the Bengali to the Arian and Aboriginal Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables; with Introductory Remarks by Lieut.-Col. E. Sabine;—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at* 9s.

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eighth Report of Committee on the Growth and Vitality of Seeds;—W. R. Birt, Fifth Report on Atmospheric Waves;—E. Schunck, on Colouring Matters;—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations;—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847;—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an introductory Notice by Lt.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at* 10s.

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phænomena of Plants and

Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds; —F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at* 15*s*.

CONTENTS:—R. Mallet, First Report on the Facts of Earthquake Phænomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and History of the British Annelida;—T. C. Hunt, Results of Meteorological Observations taken at St. Michael's from the 1st of January, 1840, to the 31st of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849;—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phænomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at* 16*s*. 6*d*.

CONTENTS:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Œconomical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds;—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phænomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850, to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at* 15*s*.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phænomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Œconomy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s.* 6*d.*

CONTENTS:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852–53; —James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Œconomy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations; —John P. Bell, M.D., Observations on the Character and Measurements of Degradation of the Yorkshire Coast; First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration;—Robert Mallet, Third Report on the Facts of Earthquake Phænomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s.*

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phænomena (continued); —Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54; —Second Report of the Committee on the Physical Character of the Moon's Surface;—W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships; Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s.*

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55; —Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-Registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18*s.*

CONTENTS;—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report on the Marine Testaceous Mollusca of the North-east Atlantic and Neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores;—Prof. Phillips, Report on Cleavage and Foliation in Rocks, and on the Theoretical Explanations of these Phænomena: Part I.;—Dr. T. Wright on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage;—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

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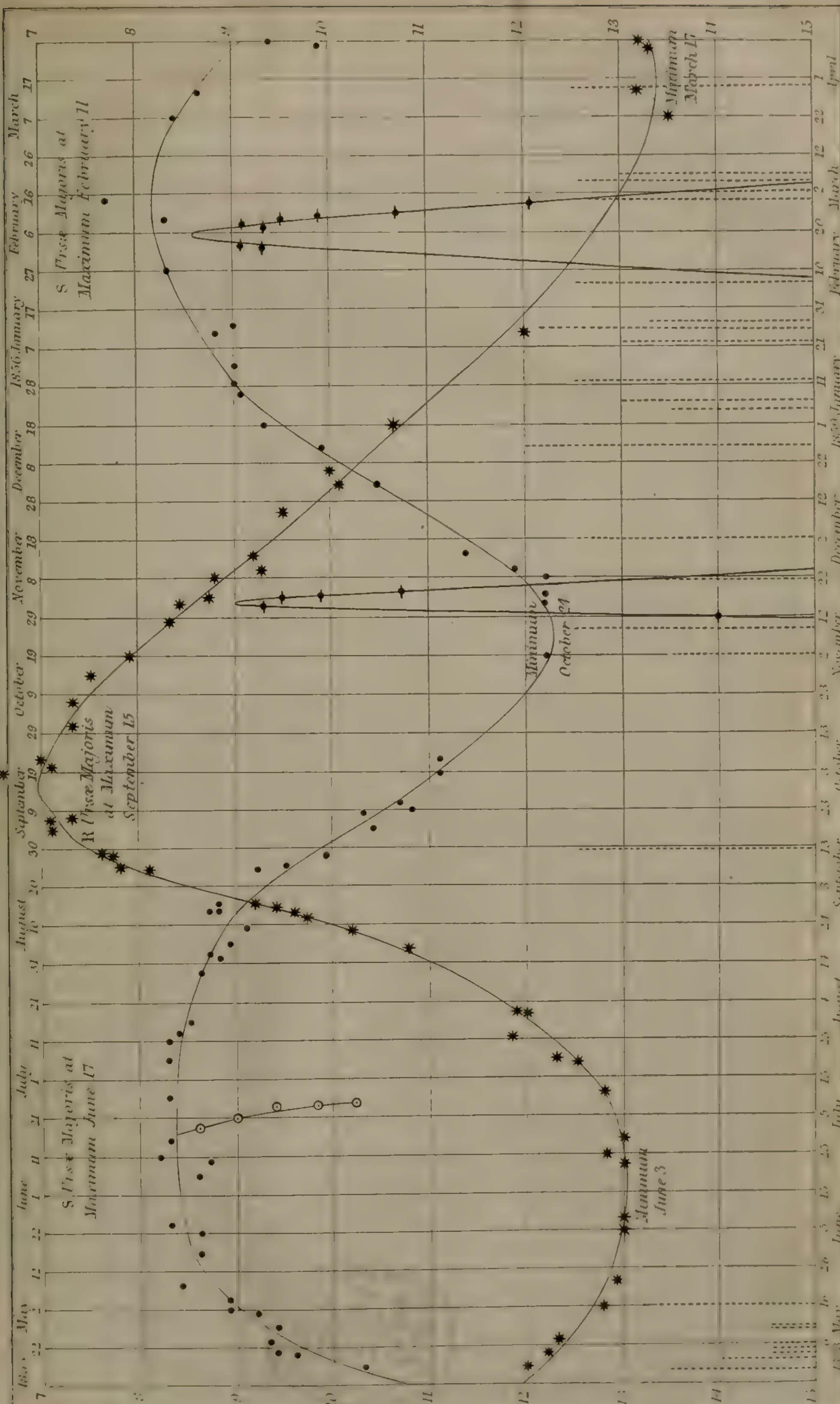
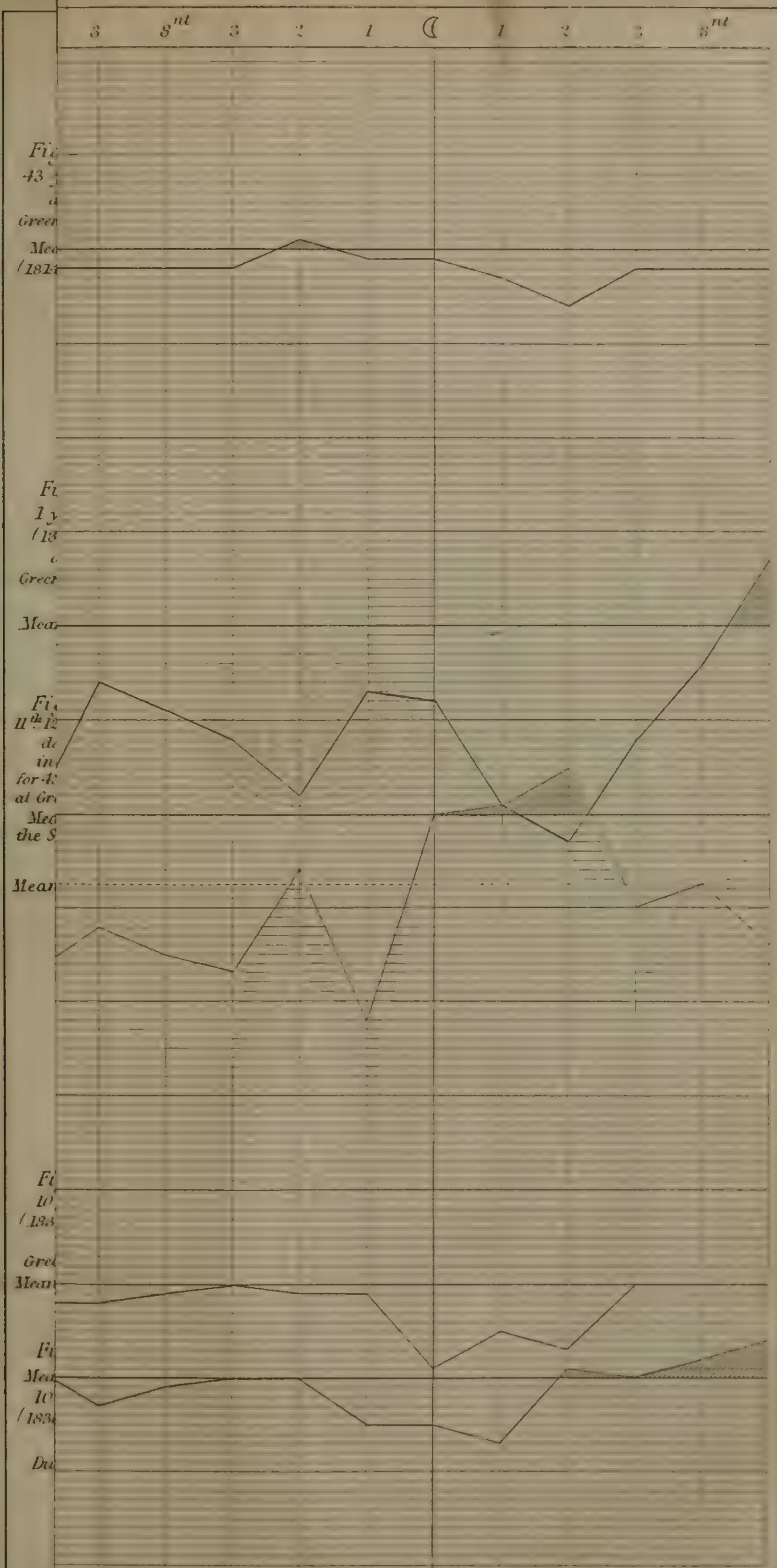


Projection of Two Maxima and Twenty six records of Invisibility of Mr Hind's Variable Star U Geminorum.

29th

Plate 2



J. Pa curves except Fig. 3.

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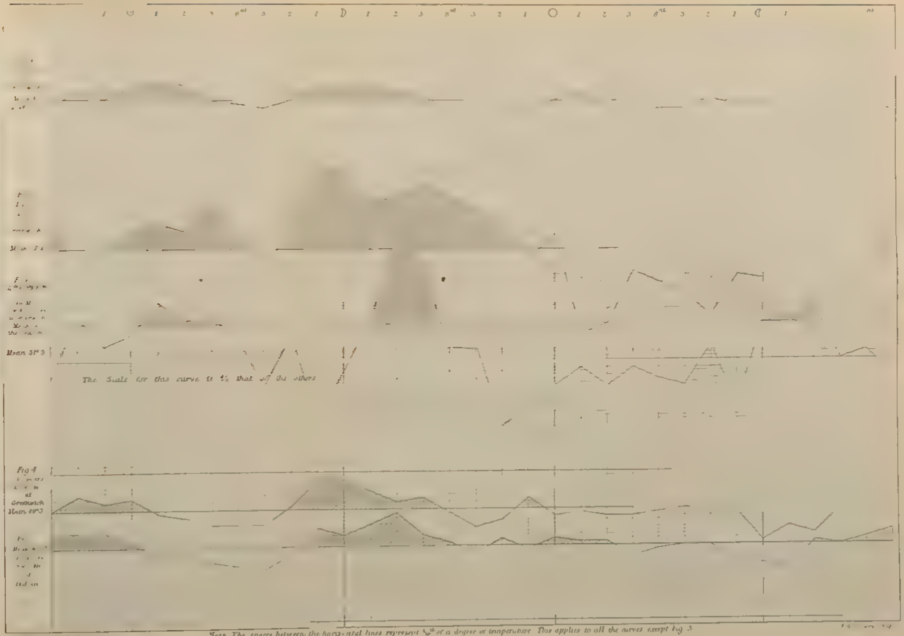
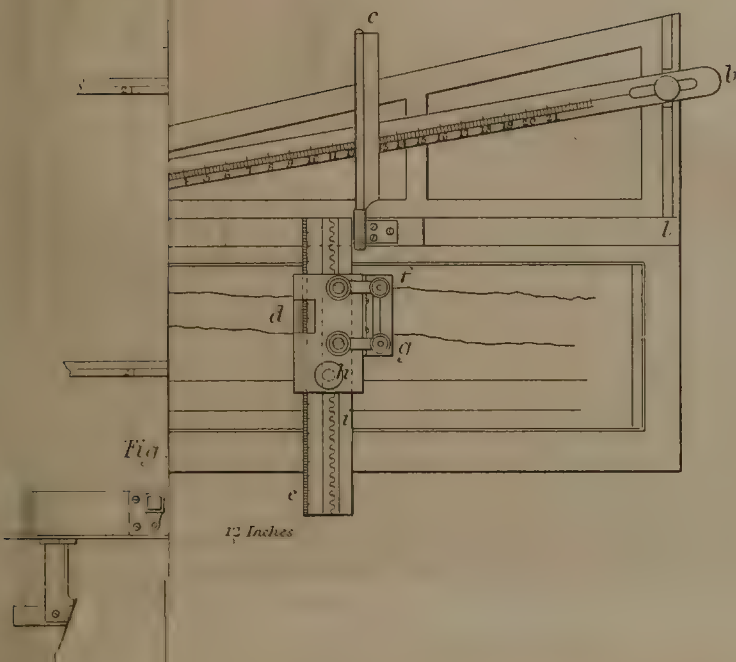
LUNAR CURVES OF MEAN TEMPERATURE AT GREENWICH AND DUBLIN



Note. The spaces between the horizontal lines represent $\frac{1}{10}$th of a degree of temperature. This applies to all the curves except fig 3



12 Inches

Fig 3 a.

J.W. Lowry fc.

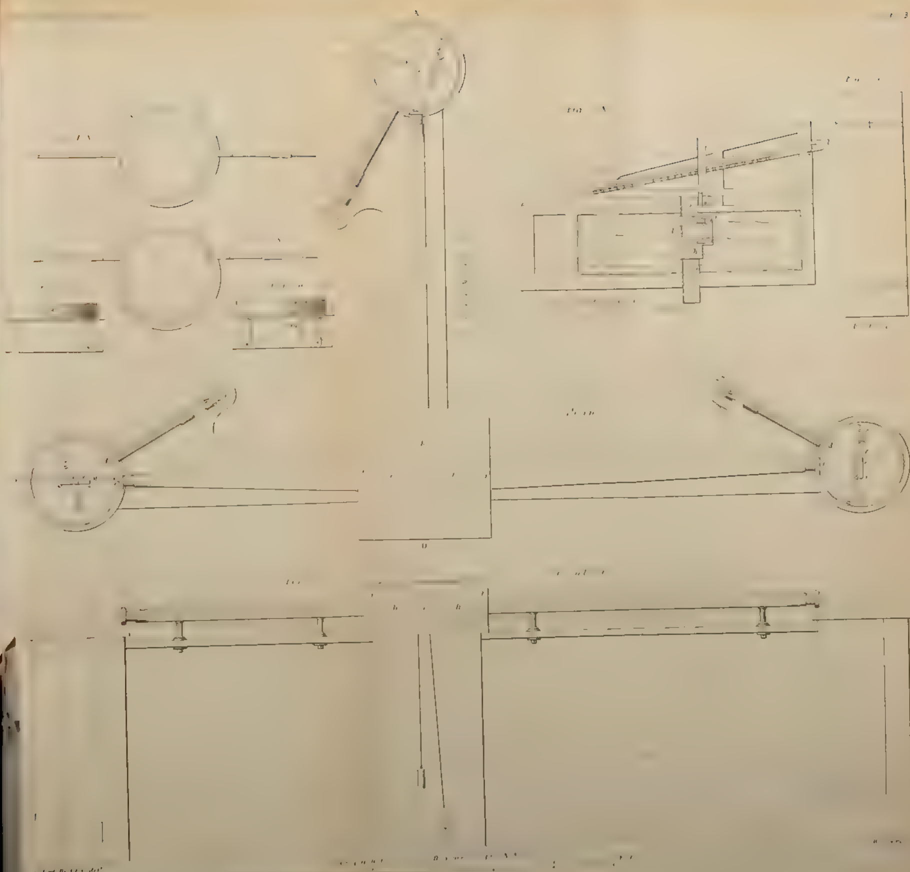
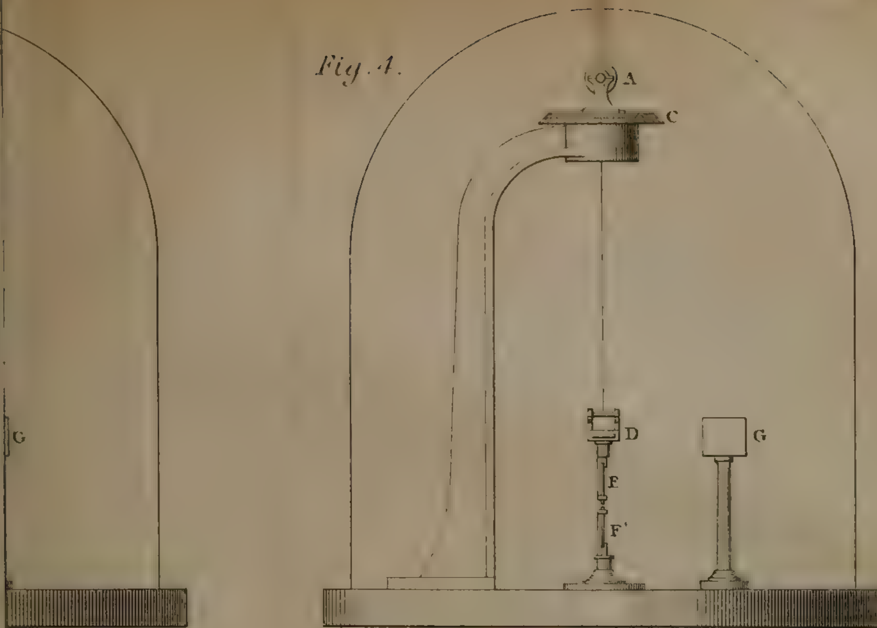


Fig. 4.



Scale 1½ inches to a foot to all figures except Fig. 7.

Inches 12 11 10 9 8 7 6 5 4 3 2 1 0 1 2 Feet.

Fig. 10. A.

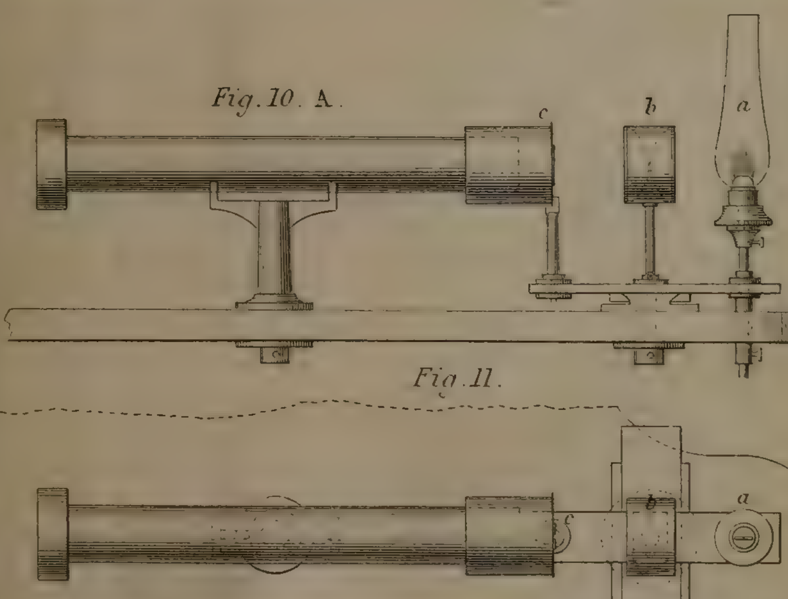


Fig. 10. a.

Fig. 11.

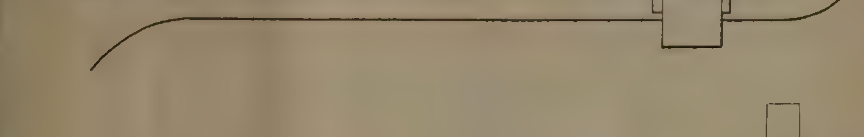


Fig. 12. A.

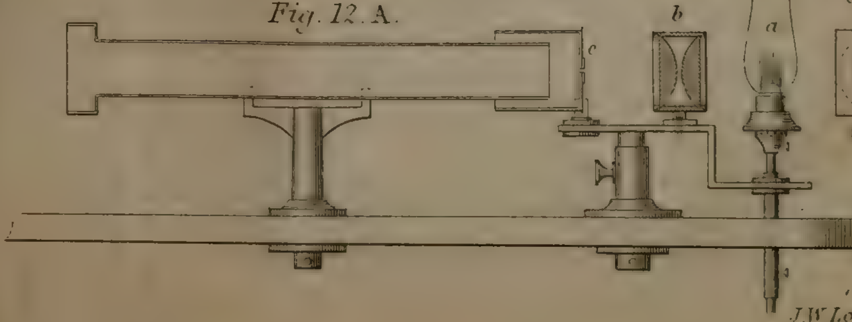


Fig. 12. a.

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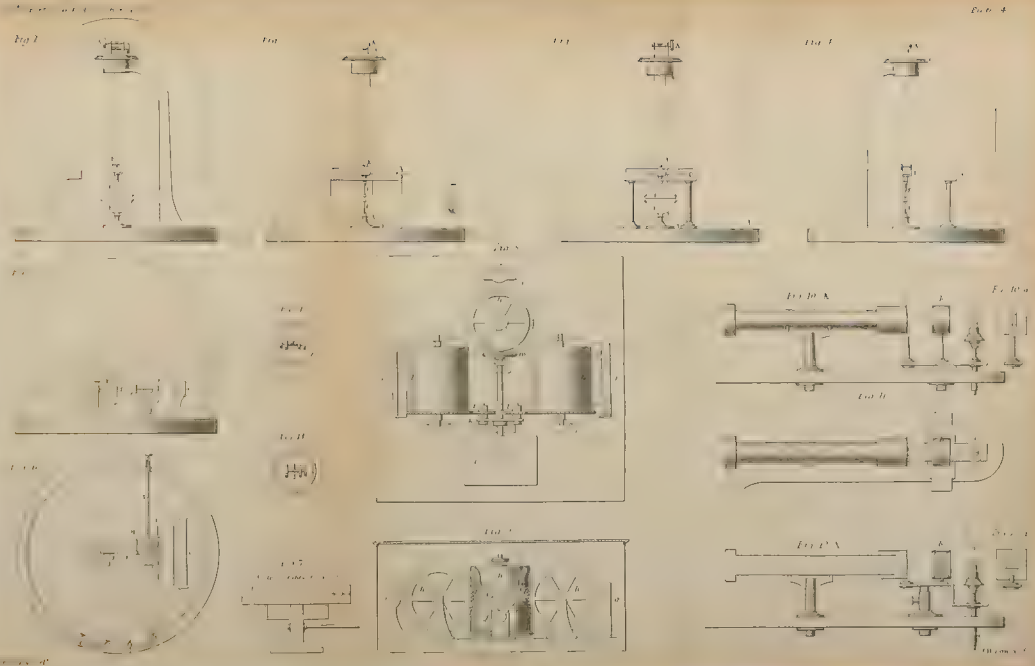
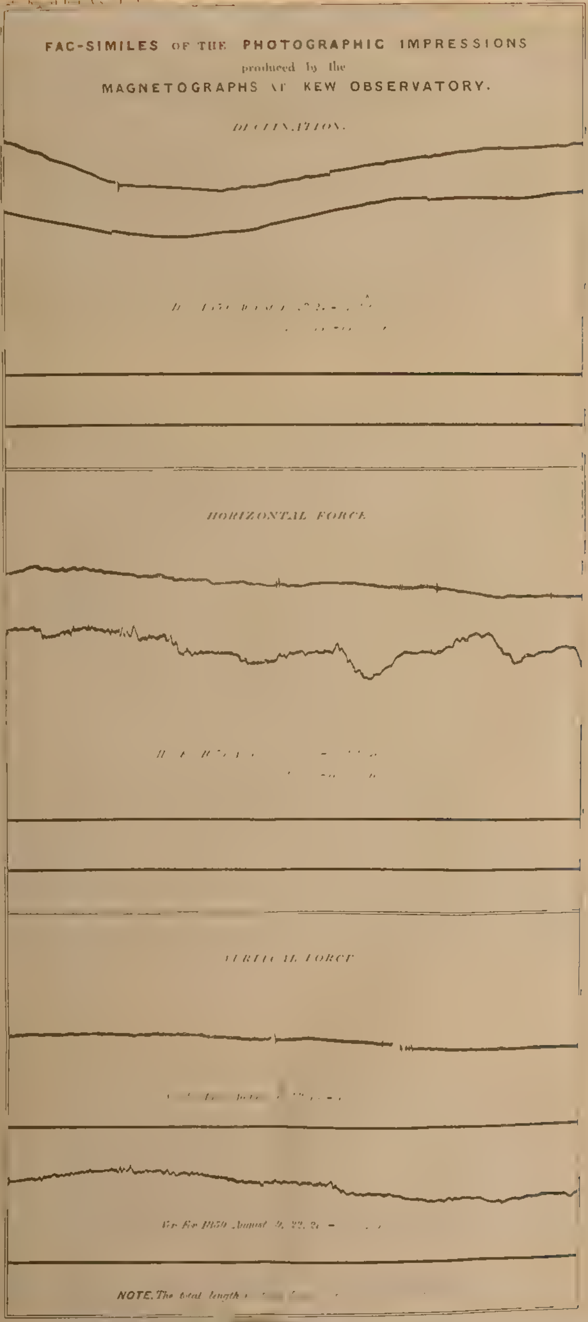
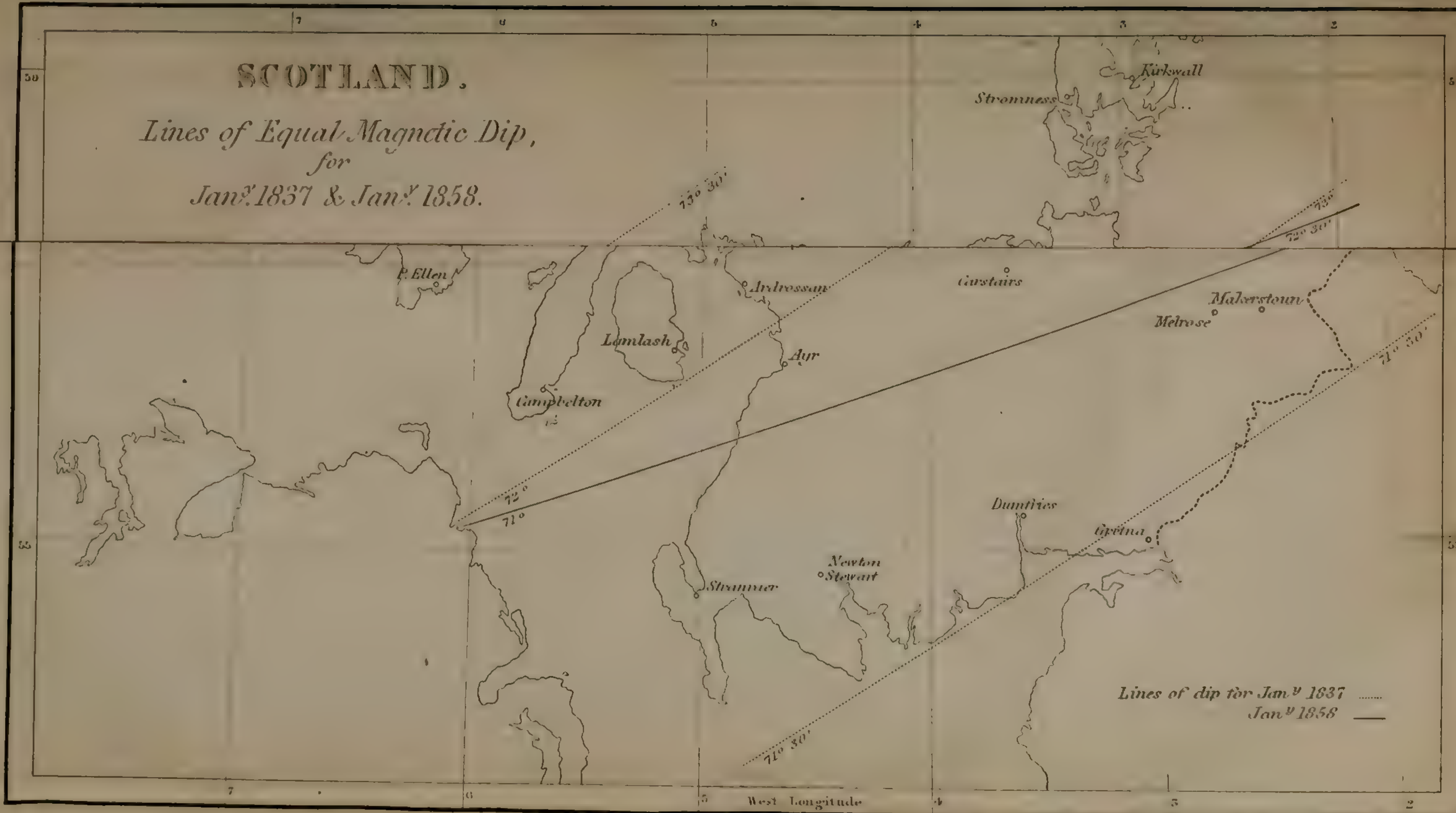
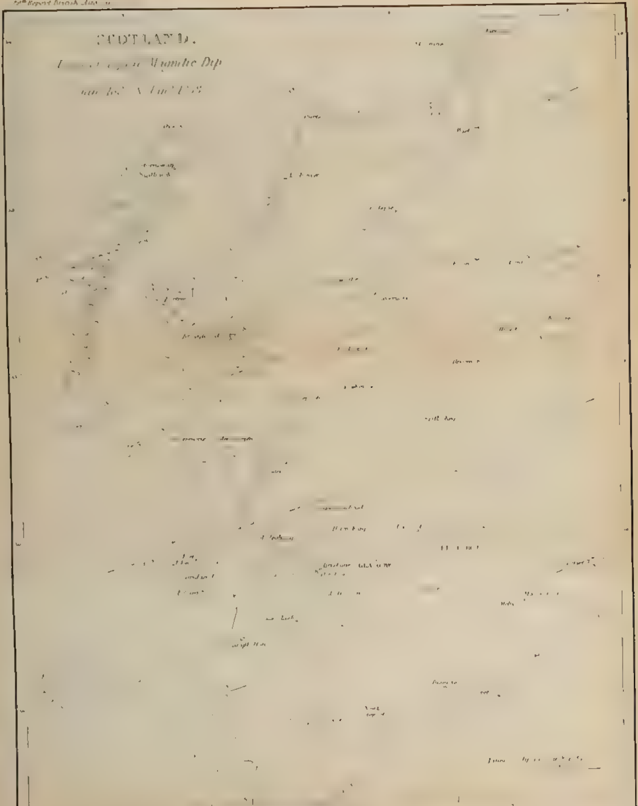
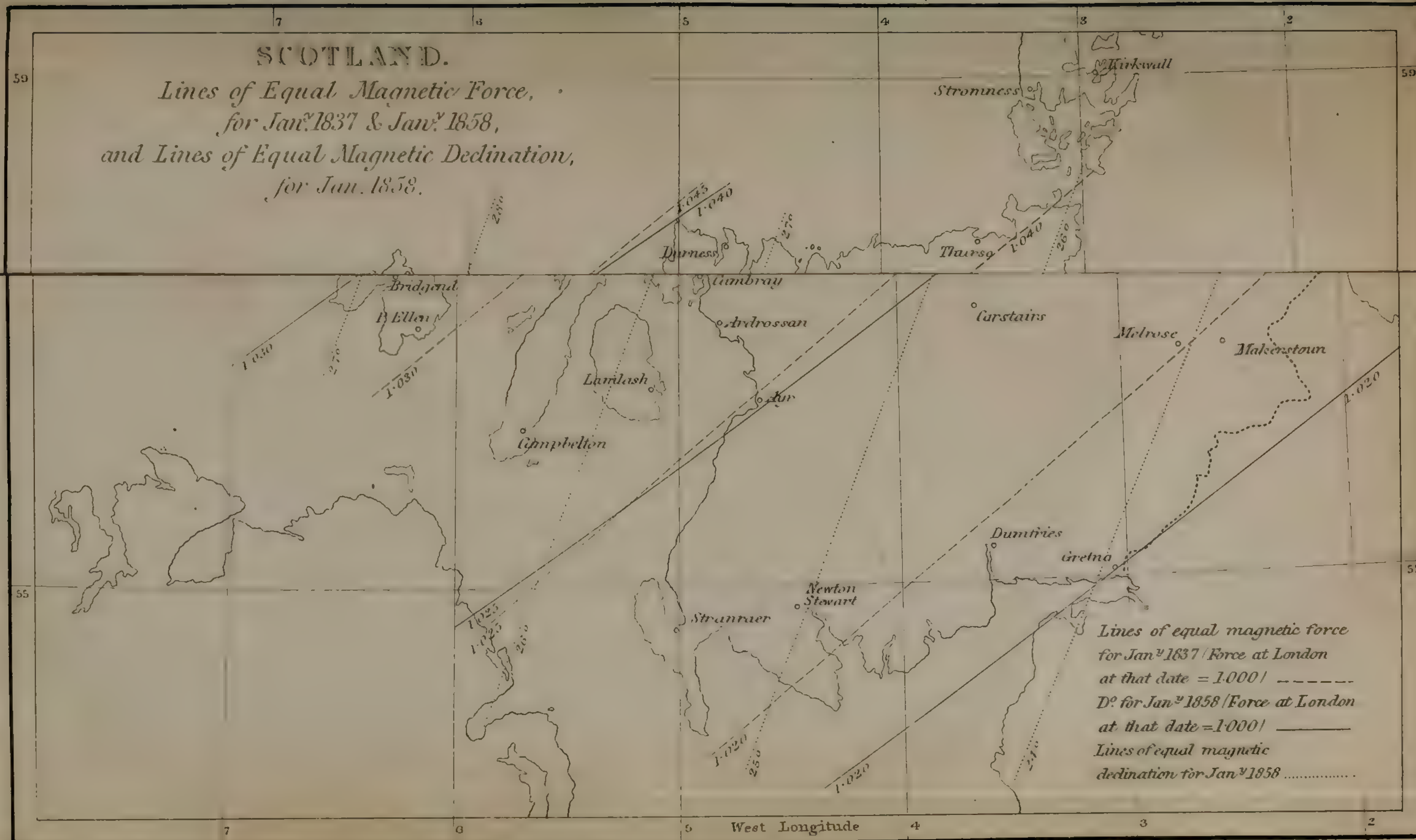



FAC-SIMILES OF THE PHOTOGRAPHIC IMPRESSIONS
produced by the
MAGNETOGRAPHS AT KEW OBSERVATORY.
DECLINATION.
HORIZONTAL FORCE.
VERTICAL FORCE.
NOTE. The total length


SCOTLAND.
Lines of Equal Magnetic Dip,
for
Jan.y 1837 & Jan.y 1858.
Kirkwall
Stromness
P. Ellen
Ardrossan
Carstairs
Makerstoun
Melrose
Lamlash
Ayr
Campbelton
Dumfries
Gretna
Newton Stewart
Stranraer
73° 30'
73°
72° 30'
72°
71°
71° 30'
Lines of dip for Jan.y 1837
Jan.y 1858
West Longitude


SCOTLAND.
Magnetic Dip


SCOTLAND.
Lines of Equal Magnetic Force,
for Jan.y 1837 & Jan.y 1858,
and Lines of Equal Magnetic Declination,
for Jan. 1858.
Kirkwall
Stromness
Thurso
Durness
Cambray
Ardrossan
Carstairs
Melrose
Makerstoun
Bridgend
P. Ellen
Lamlash
Campbelton
Ayr
Dumfries
Gretna
Newton Stewart
Stranraer
1·045
1·040
1·030
1·025
1·020
25°
26°
27°
28°
Lines of equal magnetic force for Jan.y 1837 (Force at London at that date = 1·000)
D.o for Jan.y 1858 (Force at London at that date = 1·000)
Lines of equal magnetic declination for Jan.y 1858
West Longitude
59
55
7
6
5
4
3
2